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The Proceedings contains copies of 26 of the 27 papers presented at the Symposium. Subjects included: wastewater characterization, product and by-product recovery, processing modifications, wastewater treatment, and water reuse for many different segments of the food processing industry. Industrial segments included: red meat and poultry, seafood, dairy, fruit and vegetable, and beverage.

Attendance at the two and one-half day Symposium was approximately 200 with good representation by industry, universities, consulting firms as well as state and Federal agencies.

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Atlanta, Georgia

Co-sponsored by

NATIONAL CANNERS ASSOCIATION

AMERICAN MEAT INSTITUTE

SOUTHEASTERN POULTRY & EGG ASSOCIATION

PACIFIC EGG & POULTRY ASSOCIATION

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INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

The Seventh National Symposium on Food Processing Wastes was co-sponsored with the National Canners Association, American Meat Institute, Southeastern Poultry & Egg Association, and Pacific Egg & Poultry Association. The primary purpose of these symposia is the dissemination of the latest research, development and demonstration information on process modifications waste treatment, by-product recovery and water reuse to industry, consultants and government personnel. Twenty-five papers are included in this Proceedings as well as the final registration list.

These symposia will be continued; if you are interested in participating or wish to receive additional information about the Eighth, contact:

Industrial Pollution Control Division
Industrial Environmental Research Laboratory--Ci
Environmental Protection Agency
Cincinnati, Ohio 45258

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

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EPA'S INDUSTRIAL ENVIRONMENTAL RESEARCH PROGRAM

by

Dr. Wilson K. Talley[1]

As most of you in attendance today know, the U.S. Environmental Protection Agency, EPA, was created by Presidential order in December of 1970. This was, at least in part, a result of an increased public awareness of and concern with the environment. Both the President and the Congress initiated a coordinated effort through this new agency that would, as a matter of explicit national policy, make environmental concerns an integral and important part of our economic and social life.

The creation of EPA brought together 15 different, but related, programs from several Federal Government agencies concerned with such environmental problem areas as: air and water pollution, solid waste management, pesticides, water supply, radiation, noise, and toxic substances. The overall mission of EPA is the enhancement and maintenance of environmental quality in a way that is consistent with other national goals. Specific functions performed by EPA include:

- setting and enforcing environmental standards;
- researching the causes, effects, and control of environmental problems;
- assisting States and local governments through a variety of planning and waste treatment facility construction grants;
- providing technical assistance and disseminating information on environmental problems and their solutions; and
- demonstrating how to protect and enhance the environment.

Considerable effort has been expended upon balancing our environmental goals and priorities with our national economic and energy objectives.

---

[1] Assistant Administrator, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC

Thus far, it appears that we have been successful. A recent public opinion poll states in summary: "Even during a time of recession, high unemployment and rising fuel costs, the public does not voice a readiness to cut back on environmental control programs to solve economic and energy problems."

Indeed, many of our energy and materials problems can be solved or, at the very least, reduced by a return to the old conservation ethic - "Use less, use it better, use it longer, and thus waste less."

A portion of the success of EPA's environmental programs can be directly attributed to a strong research and development program. The Office of Research and Development (ORD) provides EPA with the data and information it needs to fulfill its responsibility as a regulatory agency.

Principal outputs of ORD include:

- Information which contributes to the scientific and technical bases for regulatory standards.

- Standardized methods to measure and assure quality control in programs to assess environmental quality, implement regulations and enforce standards.

- Cost-effective pollution control technology and incentives for acceptance of environmentally sound options.

- Scientific, technical, socio-economic, and institutional methodologies that are needed to judge environmental management options and to balance these options against competing national needs.

By necessity, our research program is both multidisciplinary and multimedia in nature. It is multidisciplinary because it covers virtually every EPA area of technical responsibility and it must provide support to each of EPA's programs and regional offices. The research program is multimedia because pollution occurs in all media, especially that produced as a by-product of industry. Finally, and sadly, correction of one pollution problem (e.g., water) can result in other pollution problems, if care is not taken.

ORD's resources consist of about 1,800 technical and support personnel located in 15 laboratories and in Washington, D.C. For this fiscal year (1976), our budget is approximately $250 million. It is readily apparent that our program is not entirely in house. In addition to the research conducted by ORD scientists and engineers, we manage a large extramural grant and contract program in cooperation with colleges and universities, industrial organizations, research institutes, and State and local governments. Finally, to avoid unnecessary duplication of federal skills and capital investment, we enter into interagency agreements with other federal agencies.

We reached these operating modes over a long period of time. To accomodate to the present state, we have recently completed a reorganization of the Office of Research and Development. Among other objectives, the reorganization establishes clear lines of responsibility, authority, and accountability. We are striving to reduce the amount of paperwork, substituting closer working relationships between field research personnel and the headquarters staff. To accomplish this, I have reduced the number of administrative levels and given more responsibility to the research laboratories.

Unhappily, certain well intentioned restrictions on our operations have created a "Catch-22" situation. Chief among these is a restriction on the fraction of our budget that can be allocated to travel. The ceiling is well meant, certainly, but it fails to recognize that each of our laboratories conducts a research program national in application and largely extramural in execution. Well, the solution appears easy--simply shift from extramural to a more in-house R&D effort by hiring more ORD staff. Unfortunately, this conflicts with attempts to restrain the growth of the federal bureaucracy, so we must seek other solutions.

Organizationally, ORD is now divided into four functional offices: The Office of Monitoring and Technical Support; the Office of Health and Ecological Effects; the Office of Air, Land, and Water Use; and the Office of Energy, Minerals, and Industry.

The Office of Energy, Minerals, and Industry responsibilities include assessing, developing, and demonstrating technology to abate pollution from industrial point sources. This office also plans and administers a large comprehensive energy/environmental research, development, and demonstration program involving EPAa and 15 other federal agencies.

Within the Office of Energy, Minerals, and Industry, the headquarters staff is responsible for long range program planning and for staff support of the Office. The responsibility for implementation of the research, development, and demonstration programs of OEMI rests with the Industrial Environmental Research Laboratory in Research Triangle Park (RTP), North Carolina and the Industrial Environmental Research Laboratory, Cincinnati, Ohio.

In the industrial area, the RTP laboratory has the lead role for iron, steel and ferroalloys, petroleum refining, petrochemicals, agricultural chemicals, and textiles. The Cincinnati laboratory has the lead role for nonferrous metals, metal finishing, inorganic chemicals, specialty chemicals, rubber, plastics and organics, pulp, paper and wood products, food products, and miscellaneous industries. Note that the divisions of responsibility are by industry, rather than by medium - air, water, land - or by pollutant. This is a step toward finding complete solutions, rather than partial, suboptimum palliatives.

Historically, these industrial research programs have been concerned with the development and demonstration of new or improved, cost-effective, waste management technology with industry-wide applicability. As a result, EPA has been able to establish economically and technically feasible effluent guidelines and treatment parameters for liquid-waste discharge permits. These programs have also assisted in the implementation of ambient air quality standards and the development of New Source Performance Standards. Research of this type will continue in order to respond to the technology requirements of legislation including both the FWPCA and the Clean Air Act.

A major portion of EPA's research and development program for the food processing industry is implemented through the Corvallis, Oregon, Field Station of the Cincinnati Industrial Environmental Research Laboratory's Food and Wood Products Branch. Because of the fundamental importance of the food industry, EPA has had an active R&D program for this industrial segment for over nine years. During this time, our research staff has developed a close working relationship with industry, universities, and other Federal agencies. This cooperation is absolutely necessary, because without it, our research program would be operating without critical interfaces with other segments of the research and development community.

During the past nine years our research and development program has participated in over 100 extramural/contract and grant projects in the food processing area. Our financial contribution has amounted to over 15 million dollars. These projects have covered the whole spectrum including: secondary treatment, joint municipal and industrial treatment, process modifications, product and by-product recovery, as well as process water reuse and recycle. Some of the more significant accomplishments to date of this R&D program would include:

- Commercial demonstration of dry caustic peeling of peaches and white potatoes.

- Commercial recovery of protein and lactose from cheese whey by ultrafiltration and reverse osmosis.

- Full-scale fungal fermentation of cheese whey with recovery of fungal mass for incorporation into animal feed.

- Full-scale biological treatment systems for several segments of the food industry which demonstrated that "exemplary" effluents can be economically achieved.

- A demonstration of process water reuse (zero discharge) for the beet sugar industry.

- Commercial utilization of sugar cane bagasse and leafy trash for power generation.

- Cost-effective methods of reducing water use in poultry processing.

In addition to these, there have been over 55 other projects completed to date, with approximately 70 reports published and available to the public. Nearly all of these projects have been reported on at one of the previous six National Symposia on Food Processing Wastes. Proceedings from each of these Symposia are also available.

I would like to digress for a minute to say that symposia such as this one serve a very useful purpose. The development of new or improved processing methods, treatment systems, etc., is useless unless the information is made available to and used by industry. Therefore, I would like to personally acknowledge this year's co-sponsors: The National Canners Association, American Meat Institute, Southeastern Poultry and Egg Association, and the Pacific Egg and Poultry Association.

We have been (and still are) aware of some of the unique problems with which this industry is faced. Taken together, the various segments of the food industry have a modest R&D budget and most of it is used to insure the production of safe, nutritious foods. This requires keeping abreast of and implementing the requirements of several other Federal agencies and departments in addition to EPA such as FDA, USDA, OSHA, NIOSH, etc. Some of the food processing industry is also faced with: short processing seasons (2 months or less); significant variability in processing (hour to hour, day to day, and year to year) which compounds end-of-pipe treatment problems; very low profit margins; inability to acquire money for significant capital expenditures--whether for treatment or for plant renovation; as well as high-strength wastes (raw waste BOD of several thousand mg/l). An additional complicating factor is that a large number of the processing plants are very small; in some cases they are a family operation.

Currently, there are several significant projects underway on process modifications, by-product recovery and process water reuse and recycle. During the next two and one-half days, you will be hearing presentations on many of these. I would like to briefly mention two of these, since I believe they will be looked upon as "major milestones." Both projects have as their objective the treatment (including polishing) of the processing plant effluent water and then evaluating the quality of the treated water for potential reuse back in the processing plant. One project is at a poultry processing plant in Maryland, and the second is at a fruit processing plant in the State of Washington. Because of the complexity of these efforts, a very active and involved committee has been established for each study. Besides our industrial waste R&D personnel, the committees include participants from industry, EPA's Health Effects Research Laboratory in Cincinnati, FDA, and USDA.

The next point I would like to discuss briefly is the future. Where do we go from here? In fiscal year 1977, ORD will have approximately the same budget as it has this year. The planned budget for the industrial program will also be about the same, but there will be some changes within the industrial area. We will be looking at those industries having toxic discharges in more detail. There is also a need for additional work in assessing the magnitude of air pollution problems and the state-of-the-art for control of noncriteria and hazardous pollutants.

In ORD's recent "Report to Congress", which represents our first attempt at presenting a five-year overview, I pointed out that there will need to be a significant increase in expenditures for industrial pollution control research, development, and demonstration efforts in the next few fiscal years. This is required if we are truly serious about approaching the water quality goals of the 1980's. If this increase does not happen, the much needed control technology will not be developed and there will very likely be a significant time delay in achieving our goals.

As I mentioned earlier, EPA is aware of some of the unique problems facing the food processing industry. That is why we have had a very active R&D program in this area. There is a definite need to develop cost effective waste management systems to comply with 1983 requirements and beyond. This cannot be done exclusively through the development of more sophisticated kinds of add-on treatment technology; we need and want to encourage additional efforts on modifications in processing. In fact this very point was recently stressed by our Administrator, Russell E. Train, in his "Year-End Report to the Members of EPA." And, as an engineer, I must confess to a personal distrust of add-on and retrofit solutions as optimal.

We are making progress but we still have the greatest challenge ahead of us. Our country's commitment to environmental improvement and integrity has been, and continues to be very real. With your continued support and cooperation, I think we will be able to achieve our goal of a "quality environment" for everyone, and do it in consonance with the necessary production of food and fiber.

Thank you.

THE EPA REGION IV PROGRAMS

John A. Little, Deputy Regional Administrator
EPA, Region IV

Good morning and welcome to Atlanta--headquarters for the dogwood tree, azaleas, and EPA, Region IV. I don't want to sound like a Chamber of Commerce spokesman but, it's a fact, you couldn't have chosen a better time to visit the city.

Two weeks ago, I and others from the Regional Office, accompanied Russell Train to Tampa where we met the public at an environmental town hall meeting. And I'm happy to report that people are still very much concerned about environmental quality. Attendance estimates ran from 350 to 500. Many of them stood throughout the entire three hour question and answer session.

Questions ran the gamut from Mirex to why one of our engineers allegedly scheduled a meeting with a Baptist deacon on a Sunday afternoon.

There were a number of inquiries into the Agency's position on returnable beverage containers. We were charged with wanting to "ban-the-can." Several workers in the container manufacturing industry felt their jobs were in jeopardy. Russ assured them that was not the case. We are not trying to ban-the-can, or put anybody out of work. He stressed, and I would emphasize here this morning, each of our regulatory actions is subject to the most thorough, hardnosed economic analysis performed anywhere in government. We do this to make sure our regulations are as sound as possible and to demonstrate our good faith to the industries we regulate. It is our way of avoiding as much disruption and conflict as possible. In short, it is our way of trying to make sure our regulations are truly in the public interest.

Several years ago it was commonly believed that environmental goals and economic progress were incompatible. A number of industry spokesmen feared that compliance with environmental requirements would result in the loss of millions of jobs and the forced closing of numerous plants. Recent studies conducted by EPA and outside consultants have demonstrated that these fears were greatly exaggerated. According to the most recent quarterly report on economic dislocation resulting from environmental controls, only 75 plants have been closed during the past five years (January 1971 through September 1975) as a result of environmental regulation. These closings, many of which were only partially due to environmental factors--resulted in the loss of only 15,700 jobs--or sixteen thousandths of one percent of the total U.S. labor force.

What is more important, these losses have been more than offset by the creation of an entirely new industry--an industry devoted to the production, installation and operation of anti-pollution equipment. A recent study by a firm of Wall Street analysts for the council on environmental quality found that environmental legislation has generated an industry employing over 1.1 million new workers. What this means is that, on balance, environmental controls created seventy times more jobs than they destroyed. The message is quite clear. Environmental protection is not only good for America. It is also good for our National economy.

More than that, environmental protection is also the key to continued industrial growth. Several years ago pollution levels had reached the point where the public was unwilling to tolerate any increase until the backlog of problems had been cleaned up. Not only the environment but also the public had reached the saturation point. Public protest against growth at the expense of the environment became a political force capable of blocking growth. This makes clear a basic point: the greatest obstacle to growth is not pollution control, but the pollution itself. Thus, pollution control has become the key to growth.

As you know, a key provision of the Federal Water Pollution Control Act Amendments of 1972 was a stipulation that "It is the National goal that the discharge of pollutants into the navigable waters be eliminated by 1985." As the key mechanism in attaining this goal Congress created a nationwide federal water pollution abatement system for point sources called the National Pollutant Discharge Elimination System, or NPDES for short.

To date, Region IV has issued 519 permits to canners and food processors in the eight southeastern states. The categories include meat products (red meats and poultry), dairy products, canned and processed fruits and vegetables, seafoods, grain mill products, bakery products, sugar and confectionery products, fats and oils, beverages, and miscellaneous preparations.

We have received 11,512 applications from all types of industry in the Region and 8,095 permits have been issued. This represents an issuance total of 70 percent. We feel Region IV is doing quite well in this regard. And if we're not doing as well as we think we are, please let us know.

In closing, let me appeal to you to see that your own self interest is best served by successfully solving environmental problems. Certainly you can solve them better than anyone else. It is by now quite clear that first-class pollution control systems can be installed without destroying healthy, profitable business operations. And it also is increasingly clear that sound environmental management is the key to future economic growth.

The need for a strong commitment by American business leaders is greater now than ever before. The fact is that the environmental problems of this country are a long way from being solved and behind us. We have made a good start toward cleaning up the most offensive conditions of pollution control facilities and top-flight operation of those facilities will demand intensive attention by top management throughout the next decade.

In addition to these major problems of air and water pollution, several major environmental problems still remain to be solved. We are just beginning to understand the subtle, chronic, adverse effects which chemical compounds released into the environment may have on human health. We are now plunging ahead with mammoth efforts to expand energy production and we will have to grapple with all the problems of preventing environmental damage from those efforts. Finally, all the complex questions of siting future industrial plants and planning intelligently for economic growth are just now coming into focus.

As America faces all these challenging problems. We have a real need for constructive business leadership. The entire country has an enormous stake in the successful resolution of these problems, but no one has a greater stake in that success than you do. We in government need your help.

WHY ARE WE HERE?
AN INDUSTRY OVERVIEW

By
Walter A. Mercer
Association Senior Scientist
National Canners Association
Berkeley, California

INTRODUCTION

In each life, I believe, there are moments of time in special situations, which crystalize and become memory capsules of "happenings," - events whose associated warmth and brightness become underlined reference points in the book of memories which, in part, we compile each day of our lives. For me, this is a "happening" to be remembered - if the words chosen convey the intended message of this presentation, and the manner of their presentation arouses responsive thoughts - then, perhaps it can be noted as worthwhile.

My history of association with the birth and growth of these symposia gave me the opportunity to speak for the 70-year-old Association of the food canning industry. Sixty-three of those years measures the history of the Industry's research efforts to improve its water and waste management practices while responding to its public responsibility to expand production of safe and wholesome foods.

We are hopeful that this presentation will be in accord with the feelings and hopes of all segments of the food processing industry. We meet for this symposium, in the center of an area so important to all of us for its production and processing of poultry, as well as other food commodities. We must recognize that our future food supplies for the consumers of this Nation - and to a great extent those of the World - depend on a prosperous and productive agriculture.

At some time in the future - far, far in the future, we all hope - each of us must return to Nature those elements which we borrowed, to form the human package which is each of us. That one package - because we are human - has two recognitions - that which we think we are, and another, which those about us recognize as carrying our name. Regardless of personal, or society's evaluation of our worth, in Nature's materials analysis scheme, we are not much:

Water enough to fill a 10 gallon keg,
Fat for seven bars of soap,
Carbon for 9,000 writing pencils,
Phosphorus for 220 matches,
Magnesium for one laxative dose of salts,
Iron enough for one nail,
Enough lime to whitewash a chicken coop, and
Sulfur enough to rid one dog of fleas.

To these and other materials essential to the structure and functions of the human body, must now be added traces of chemicals not a part of our original birthright - unavoidable because we did not in the past - nor is it possible now, or in the forseeable future, to live in an environment completely free of man-made organic and chemical substances.

Industry - Assigned Significance of This Symposium

On a day in November, 1968, in Berkeley, California, a discussion group consisted of representatives from the food processing industry, various universities engaged in food related research, and state and federal agencies concerned with agricultural production and the environmental problems resulting from the growing and processing of foods.

Other participants in this first, full-scale, two-day, meeting of the National Canners Association's Technical Committee on Environmental Research, were four staff members of the, then, Federal Water Pollution Control Administration:

Mr. James Boydston and Mr. Kenneth Dostal from the Pacific Northwest Regional Laboratory at Corvallis, Oregon.

Mr. George Keeler, Research and Development Grants Program, Washington, D.C., and

Mr. William Pierce of the California - Nevada Basins Project Team.

In the years, which have followed, these and other EPA staff people have participated in other food industry meetings. At that first meeting it was my privilege, to outline a proposal previously endorsed by a number of industry and university persons. Essentially, the proposal called for the organization of an annual workshop, or similar-type forum, for presentation, discussion, and distribution in printed form, of environmental research results obtained by industry, government and universities.

The first fruit of the proposal, and its discussion, was the concept of national symposia to be co-sponsored by government and industry. The First National Symposium on Food Processing Wastes came in April, 1970, in Portland, Oregon.

James Boydston, Chief, Waste Treatment Research Program, in the Federal Water Quality Administration's Pacific Northwest Water Laboratory, presented the objectives of that first symposium. I quote, in part, from his remarks:

> "This meeting beginning today marks a milestone, I think, in the National program of research and development of water pollution control methods for the food processing industry. The program will, I hope, be the first of a continuing series of symposia - to make current information available in open forum meetings of

> this type, and to give you an opportunity to question those experts who are actually developing and demonstrating new and improved treatment methods."

I continue to quote:

> "This meeting marks a further milestone in that it truly represents a cooperative, coordinated program between industry and government, to mutually solve troublesome water pollution problems. This cooperation is demonstrated by the (government-industry) co-sponsorship of this meeting."
>
> "Our research goals should include the refinement of conventional methods of treatment; the development of processes capable of higher degrees of treatment or completely closed-loop systems where the treated effluent is reused within the processing plant; efforts should be expanded on processing methods to reduce the quantity of water required per ton of product; finally, to develop profitable by-products from the wastes resulting from current processing methods."

Mr. Boydston's closing remarks were prophetic and full of promise, I quote:

> "In closing let me say that we are faced with serious challenges: we have a deteriorating environment and an aroused public. We know a few answers and a lot of problems. But, I think that cooperation such as shown here today between industry and government can make the food processing industry a leader in the fight for clean water."

That First Symposium received an enthusiastic response from industry, suppliers to the industry, universities, and government leaders. The obvious result was the scheduling of the symposia on an annual and regional basis.

Mr. Carey, speaking as President of the National Canners Association, wishes me to express our appreciation and gratitude for the opportunity, over these seven years, to be recognized as a co-sponsor of this National Symposium on Food Processing Wastes. The intensive planning which has always gone into each Symposium has resulted in comprehensive coverage of environmental research dealing with the many facets of water use and waste generation in the production and preservation of foods of all kinds. In looking backward, from this time, near the end of a career of research efforts in a broad area of food industry problems, I recall with pleasure and gratitude the many government-industry committee assignments and the responsibilities for cooperatively-financed, government-industry research efforts.

Associated with these bench-mark events of the past and present, are the personal relationships and channels of communication formed with the technical and scientific staff of the government activity now known as the Environmental Protection Agency. My experiences reach back to the days when the U.S. Public Health Service was still responsible for water quality and pollution abatement research. Members of the Association staff and the food canning industry, which we represent, wish to express our sincere appreciation for the unique and fruitful relationship out of which came opportunities to assist in the development of water quality criteria and the technical and economic data needed for establishment of environmental control regulations expected to be reasonable and attainable, and to allow economic survivial.

We are particularly grateful to that EPA team located in Corvallis, Oregon and the Research and Development Grants Branch in Washington, D.C. Many names could be recited in recognition of their unstinting efforts to assist us in characterizing and accurately describing the unique complexity and diversity of the food processing industry. Over the years, working together on demonstration projects - or separately, but mutually interested and concerned - we have developed technological and economic data for inplant process modifications and innovations, which are now in use or will be used if time is permitted for the necessary engineering and economic adjustments.

Of immeasurable value have been the contributions made by these and other EPA scientists to our knowledge and research capabilities devoted to the treatment and management of residual food materials. Government printing and distribution of the symposia proceedings have provided a virtual library of reference materials applicable in many ways to the technical aspects of environmental problems.

We interpret a portion of the report of the National Commission on Water Quality as recognition of the value of this EPA scientific input into solving the environmental problems of low-profit margin industries in regional areas. I quote from the Commission's report:

> "Finally, the results of many (of the) studies point to a need for technical advisory services to the localities and to small industries. The compliance requirements are technically, legally, and administratively complex. The planning requirements and their long-term implications reach beyond the capacity of many small or even moderate-sized communities to cope."

I continue to quote:

> "The Commission is convinced that such a field advisory service, operating out of regional offices of EPA would help localities, states, and the Federal government save money. It would help to expedite grant applications. It would help to assure that communities select the best long-range treatment option, in terms of cost effectiveness and environmental quality. Properly staffed, it could also be an essential information clearing-house to keep localities and industries abreast of innovative technologies and economically and environmentally preferable solutions to their individual treatment problems."

This recommendation and others, in the report, are completely in line with my industry's experiences with EPA scientists - a rewarding and profitable association in the best meaning of industry-government cooperation. Mr. Carey wishes me to add this special message which I now quote:

> "The lofty intent of the American public to protect our environment was imperfectly translated into laws by the Congress. Those laws are being imperfectly translated into regulations and the regulations themselves are being imperfectly enforced. In too many cases these successive distortions have resulted in actions which are unrelated to the basic intent of environmental protection."
>
> "You who have scientific and technical competence are the ones who we must look to to keep all of the machinery properly directed. While you may not control the legal machinery itself, you are the advisers upon whom all must lean."

That is why we are here today.

What Will Happen to Food Production?

On Sunday, March 28, 1976, at some minute during that day, the World's population reached four billion human individuals. More than one-third of that population is under the age of 15 years.

Although the World's population is growing at a slightly slower rate than our experts believed a year ago, many of those just under 15 will soon reach their child-bearing years.

During the last 16 years, the World's population grew from three billion to four billion. Only 13 more years will be required to reach a count of five billion humans on Earth.

Each day, somewhere, babies are born to approximate 328,000 in numbers. The estimated 133,000 deaths each day leave us with a net increase of 195,000 new humans - 135 new humans each minute of each day - 2.25 food-dependent humans each second of each minute.

Who will provide the food, clothing, medical care, educational opportunities, the hope that anesthetizes the misery of hunger and illness?

In our United States, we have five percent of the World's population. By mid-July we will have 215 million Americans - 86 times more than we had 200 years ago.

Today, this opening of the Seventh National Symposium on Food Processing Wastes, marks the passing of an interval of time within which technical groups of the various segments of the food industry have worked, increasingly, to obtain, organize, and explain, for government teams, the complexities of food processing operations: non-continuous seasonal operations, variabilities between processing of different products, and the differences in water use and waste discharges for the same plant processing the same product. It was our hope that detailing such complexities would enable the promulgators of effluent control regulations to utilize the individual industry economic evaluations and cost/benefit equations which were the intent of Congress.

In the meantime, and for many years in the past, the industry has moved as rapidly as possible - considering its operational burden of more than 2000 federal food regulations - to establish the controls required to prevent excessive and unneeded discharge of organic food residuals into the streams of the Nation.

For mid-December, 1975, the Arthur D. Little Opinion Research Corporation, summarized interviews with more than 1,000 persons over 15 years of age. Responses from those interviewed were the basis for ranking public concern about 30 national issues. Seventy percent of the persons interviewed ranked the "high cost of food" as the number one national problem of most personal concern. Inflation was placed third in the listing of personal concerns for 62 percent of those interviewed.

Placed 10th in the listing of 30 national issues of concern was air and water pollution. This matter of personal public concern was ranked equally with "problems of the elderly" by 45 percent of the respondents.

Today, consciously or not, we, the people - the food consumers - have thrown a challenge to the World's agriculture - double your production in 25 years!

As previously indicated, the World's population is expected to double before the end of this century - 24 years from now. Today, at the beginning of each new Earth Day - almost 200,000 new mouths to feed.

Agriculture and food processing must grow, process and distribute almost as much additional food as is now produced. If we meet the additional need of improving the diet of the World's people, at the same time, World agriculture must more than double its production - in one generation.

The last doubling of food production by the World's farmers required 35 years - now it must achieve a doubling in 25 years.

In one form or another, government takes one out of every three dollars we earn as a nation of people. Even though, the bite is already that deep, we as a people continue - or remain silent but concerned - when self-appointed consumer protectors demand more government programs - leading to federal, state and city budget deficits - and meddling in our private business and personal affairs.

The public needs to recognize that a double-edged regulatory system that outlaws insect and mold fragments in food, on the one hand and severely restricts the development of pesticides on the other, is bound to reduce agricultural production efficiency, increase food costs, and reduce the quantity and quality of the food produced.

Other Conflicts in Regulations

Unfortunately, other Federal agencies have brought on a proliferation of regulations which are both conflicting and confusing. The result is that the environmental problems of food production and processing are becoming increasingly difficult and costly.

Examples include the following:

Aerators, to meet wastewater treatment standards proposed by EPA, which generate noise exceeding OSHA standards;

Power-driven equipment required for EPA waste treatment compliance that uses excessive amounts of energy (FEA).

Porous noise insulating surfaces (OSHA) that do not meet FDA and USDA sanitation requirements, and

EPA proposed recycling of food processing waters to minimize liquid discharges or reuse of treated wastewaters as opposed to FDA responsibility for the safe use of such waters as they affect the wholesomeness of processed foods.

Recently, Mr. S. Donald Wiley, Chairman of the Board of Directors, National Canners Association made this eloquent plea, which I quote as follows:

> "To all who speak for the consumer - for that body of diverse individuals we call the public - we extend an invitation to work toward goals of environmental improvements - scientifically determined to be needed - and demonstrably achievable goals - which will allow the grower and processor of foods to survive and to continue the increasing production of foods - not only for ourselves but, whenever possible for those who need and must have our grains and other foods to survive."
>
> "The food processing industry - all segments - growers and processors - that constitute the whole of Agriculture - ask only that regulatory agencies, including EPA, require of us only that which is truly in the best interest of, and desired by, the silent majority of the people for who you speak and act - that you weigh as prudently as possible, each action which you feel is a step in the stairway of regulation on regulation - intended to reach the pronounced goal of an eco-system restored to its virginal purity."

Mr. Wiley concluded these remarks with the following:

> "Any legislation, any regulatory procedure, which affects directly or indirectly, the growth and processing of foods should be carefully

> weighed against the possibility that it may impede the production of food or push its costs beyond the financial reach of any significant segment of our people."

Because of the continuing, concerted effort to impose "humanistic" science over objective science, books, and articles, and television dialogues have dealt, emotionally, with chemicals in the environment. Without authentic evidence they stand guilty, until proven innocent, of many of the pollution ills and health disorders of current concern to the general public.

Food additives, animal feed additives, cosmetics; air, water and chemical emissions from factories, the burning of fossil fuels - each and all have been selected, at times for attack by consumerists and ecologists.

Extraordinary attention has been given to pesticides, plant growth regulators, and chemical fertilizers. Groups and associations have been formed to mount opposition to their use - opposition so furious and tenacious as to be astonishing in its degree.

An now, to add the ultimate in confusion to that already created in the public mind, we have the February, 1976, EPA presentation to the National Press Club, included was the statement which I quote.

> "Most Americans had no idea, until relatively recently that they were living so dangerously. They had no idea that when they went to work in the morning, or when they ate their breakfast - that when they did the things they had to do to earn a living and keep themselves alive and well - that when they did things as ordinary, as innocent and as essential to life as eat, drink, breathe, or touch, they could, in fact, be laying their lives on the line. They had no idea that without their knowledge or consent, they were often engaging in a grim game of chemical roulette whose results they would not know until many years later."

End of quote.

Apparently, we are to expect that Mother Nature will give us abundance and yet live up to some degree of virginal purity and allure which she never possessed at any time since or before Earth became man's home.

The original Georgia Colony in the 13th Century almost perished from epidemics of disease and poisonings caused by the foulness of the streams polluted with the up-stream carcasses of dead animals and decaying plants.

There were no trout in the Missouri River that Lewis and Clark explored all the way to today's Montana. The water was too muddy.

There were no game fish in the Colorado River when Coranado gave it its name - because of the heavy load of red silt borne seaward by the river.

Our forefathers took Nature as they found it - and were content with it. They endured storms, droughts, and disease - caught fish when they would bite, dug wells for drinking water, tossed their slops out through the back door - and prayed for rain for their crops and protection from the hordes of pests that came, as imagined punishment, for their transgressions.

What About Cancer and the Environment?

In May, 1974, the National Center for Health Statistics made the report that death rates from heart disease, cancer, strokes, and six other diseases had declined over the past 20 years - but nobody can say why.

Data were gathered from 33.6 million death certificates recorded in the United States in the 1950's and 1960's. These data showed declines in 9 of the 15 leading causes of death among Americans and increases in 6 others - accidental deaths, suicides, homocides, and deaths from cirrhosis of the liver were among those on the increase.

The American Cancer Society's Environmental Cancer Research Project began in 1974 to attempt to answer questions about how environmental changes affect people. Prominent in the search for data is confirmation of the statements alledging that some 85 percent of cancer is derived from environmental causes - causative agents in air, food and water.

In selected situations, there can be no serious argument that prolonged exposure to lung irritants such as asbestos, coal dust, irritants in smoke and certain volatile chemicals may cause lung cancer, there appears to be a connection between long exposure to unusual concentrations of certain chemicals and liver cancer for workers in the manufacturing process. Industrial workers should and can be protected against such hazards.

A recent publication of the American Cancer Society revealed that in a survey of cancer deaths around the world - with more than 20 countries included - Scotland has the highest cancer death rate for men while Denmark and Chile rank equally as number one in the highest rates for women.

On the other hand Nicaragua has the lowest cancer death rate for both men and women. From the top of the list of about 22 countries, the United States is in the 18th place, from the top, for men and 19th for women. As compared to the number of deaths after diagnosis and treatment for cancer, since 1937, there has been a 65 percent increase in the number of those who live beyond the crucial 5-year period. But lung cancer is on the increase. I think we know the causes. I am told that 75 percent of these cancers are preventable. There is not one shred of evidence, or even a basis of reasonable suspicion that any human damaging effects have ever been caused by any traces of pesticides in foods consumed in the United States.

Certainly some defects have been observed in test animals fed or injected with exceedingly large amounts of some agricultural chemicals. But it is a long, long unscientific step from the observation of the effects of such abnormal

This does not mean to say that we have no environmental problems to solve. The task before us will require the industrialist, government official, scientist, and citizen - each must play an important role - but it must be a symphony of effort in which all of the risks, the costs, and the benefits are known. Our World, as we know it today, depends on this.

That is why we are here.

A WASTEWATER TREATMENT STUDY FOR SKOKOMISH SALMON PROCESSING PLANT***

by

Dr. S. S. Lin*, Dr. Paul B. Liao* and Max W. Cochrane**

INTRODUCTION

The Skokomish River supports a large Indian commercial fishery which enables tribal fishermen to supplement their income and food supply during the fishing season. With no means for preserving the fish other than smoking, much of the harvest is marketed as fresh, which often results in a weak market position for the fishermen and quality loss in the fish.

A salmon processing plant was built to provide a more efficient system for handling the fishery resource. The plant, designed by Bosworth and Carroll, consists of a fish-preparation area, smokehouses, refrigeration and freezing capacity, and a retail outlet. The plant markets fresh, fresh-frozen, and smoked-fish products. Freezing capacity allows the plant to smoke fish continuously throughout the year. The location and layout of the salmon processing plant are depicted in Figures 1 and 2, respectively.

Pre-bled salmon were used for processing in the past. However, fish now are hand butchered at the plant. This increases blood and solids in the waste flow and imposes a higher loading in the wastewater treatment facility.

In 1973 EPA and the Washington State Department of Social and Health Services informed the Skokomish Tribal Council that wastewater generated at the salmon processing plant must be treated before discharge into receiving waters in order to meet effluent-limitation standards. The Council retained Kramer, Chin & Mayo, Inc. (KCM) to provide technical

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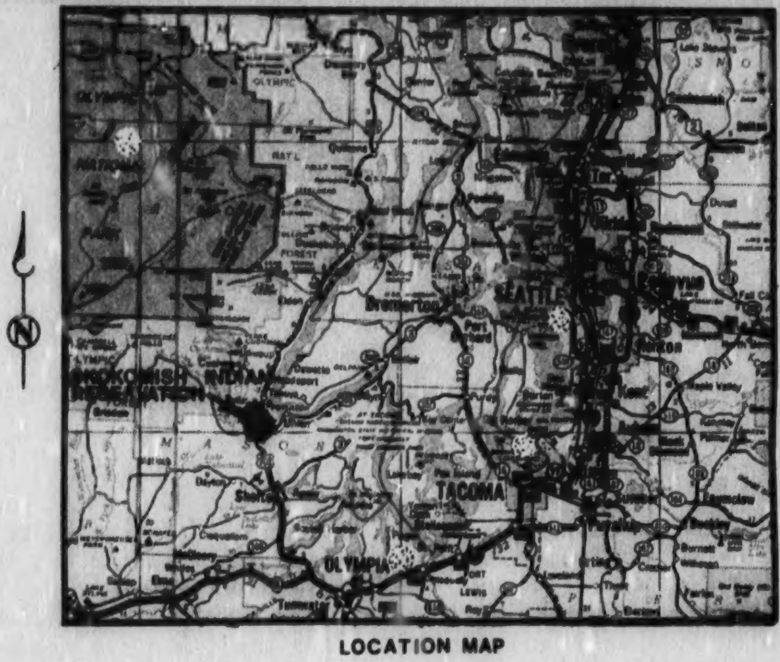
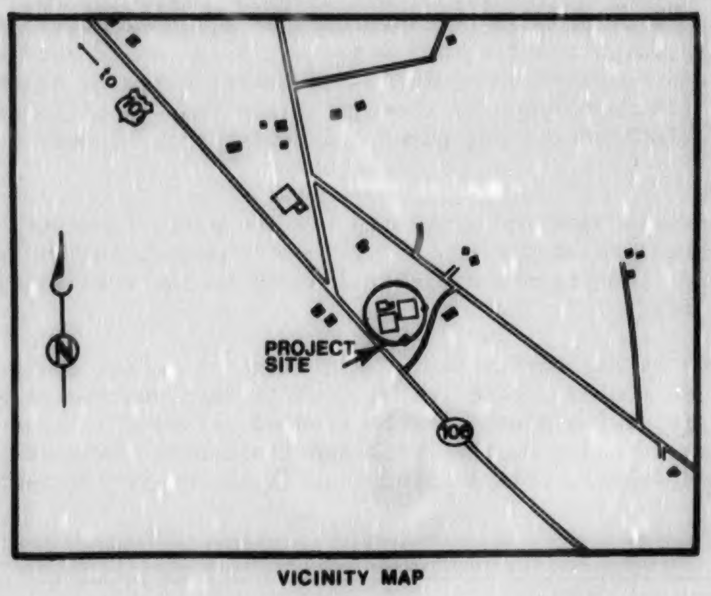
*Kramer, Chin & Mayo, Inc., Consulting Engineers, Architects and Applied Scientists, 1917 First Avenue, Seattle, Washington.

**Environmental Protection Agency, Corvallis, Oregon.

***This project was sponsored by the Environmental Protection Agency, under Grant No. 803911, and the Skokomish Indian Tribal Council, Shelton, Washington.


N
SKOKOMISH INDIAN RESERVATION
Bremerton
SEATTLE
TACOMA
OLYMPIA

LOCATION MAP


to 101
PROJECT SITE
106
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VICINITY MAP

FIGURE 1 LOCATION AND VICINITY MAPS
SKOKOMISH PROCESSING PLANT
SHELTON, WASHINGTON

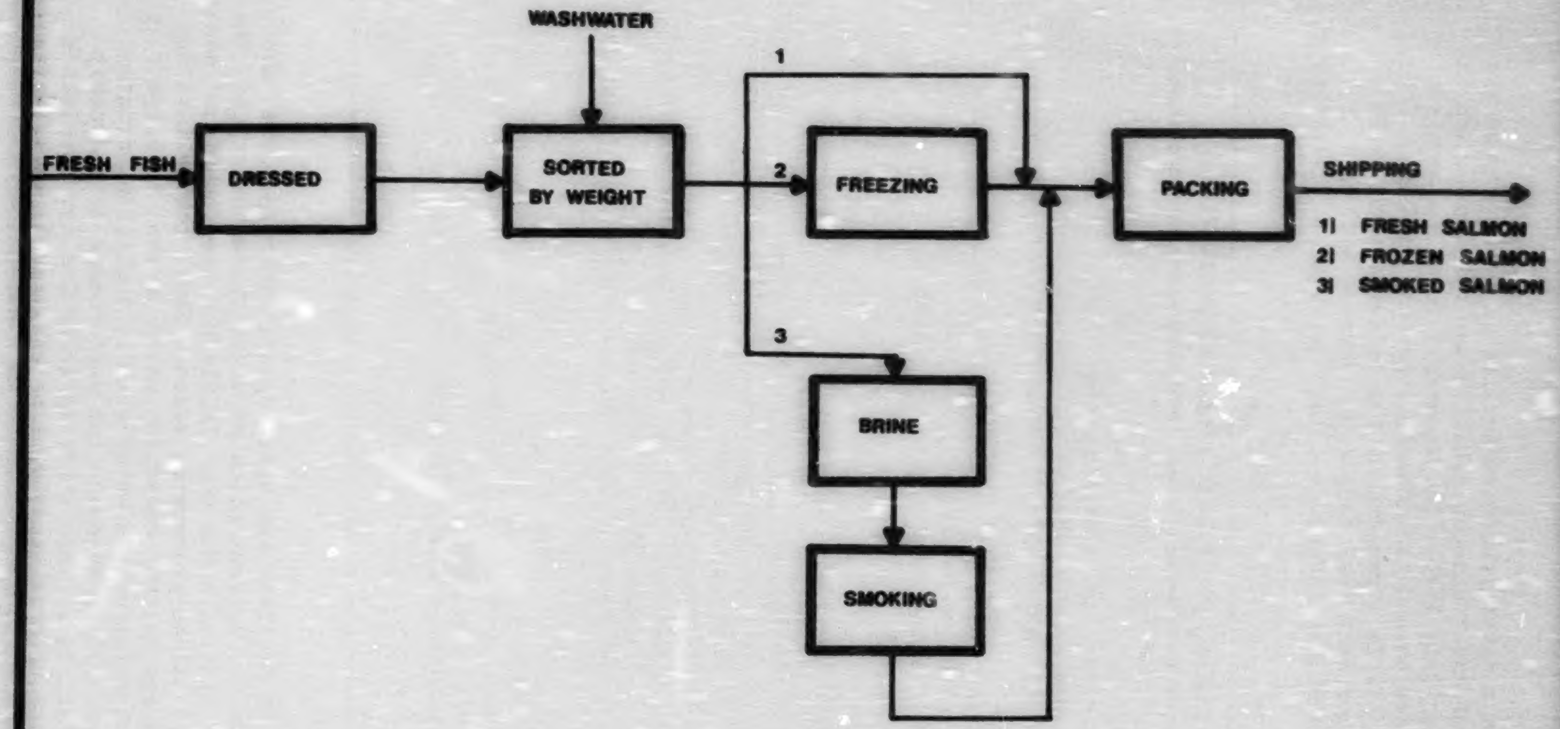

WASHWATER
FRESH FISH
DRESSED
SORTED BY WEIGHT
1
2
3
FREEZING
BRINE
SMOKING
PACKING
SHIPPING
1) FRESH SALMON
2) FROZEN SALMON
3) SMOKED SALMON

FIGURE 2 PROCESS LAYOUT OF SKOKOMISH SALMON PROCESSING PLANT SHELTON, WASHINGTON

services and to design a waste-treatment facility for the processing plant. Construction of the treatment facility was completed, and has been in operation since July 1975. The treatment facility consists of an extended-aeration system and two identical aerobic polishing ponds, as shown in Figure 3. Table 1 summarizes the criteria used in the design of the wastewater treatment facility. Treated effluent is disposed of in the drainfield through a 6-inch perforated plastic pipe.

TABLE 1. SUMMARY OF DESIGN, WASTEWATER TREATMENT FACILITIES

Waste Characteristics

Source = Process water, no sanitary waste
Minimum Flow = 0 gpd
Maximum Flow = 20,000 gpd
Peak Flow = 18 gpm
Daily Flow Variation = Continuous over approximately 18 hours
Average BOD Concentrations = 500 mg/1
Average Suspended Solids Concentration = 100 mg/1
Maximum BOD Loading = 80 lb/day

Extended Aeration System

Aeration Tank:
Volume = 20,000 gallons
Detention Time at Maximum Flow = 24 hours
Maximum Oxygenation Available = 240 lb O_2/day
Maximum Loading = 0.03 lb BOD/cu ft/day

Clarifier:
Volume = 3,000 gallons
Detention Time at Maximum Flow = 2.7 hours
Surface Area = 98 sq ft
Overflow Rate at Maximum Flow = 202 gpd/sq ft

Polishing Ponds

Surface Area = 0.37 acre
Loading at Maximum Flow = 21.5 lb BOD/acre/day
Volume = 364,000 gallons
Detention Time at Maximum Flow = 18 days

Design of the treatment facility was based upon literature review and daily grab samples for the determination of waste characteristics. The literature review was limited since very little has been published about the characteristics of salmon-processing waste. Thus, the reliability of biological systems for salmon-processing waste-control is subject to verification and substantiation. A water-quality monitoring program was begun in September 1975 to evaluate the performance of the newly installed treatment facility. This study is scheduled for completion in March 1977. Results of this study will be analyzed 1) to determine

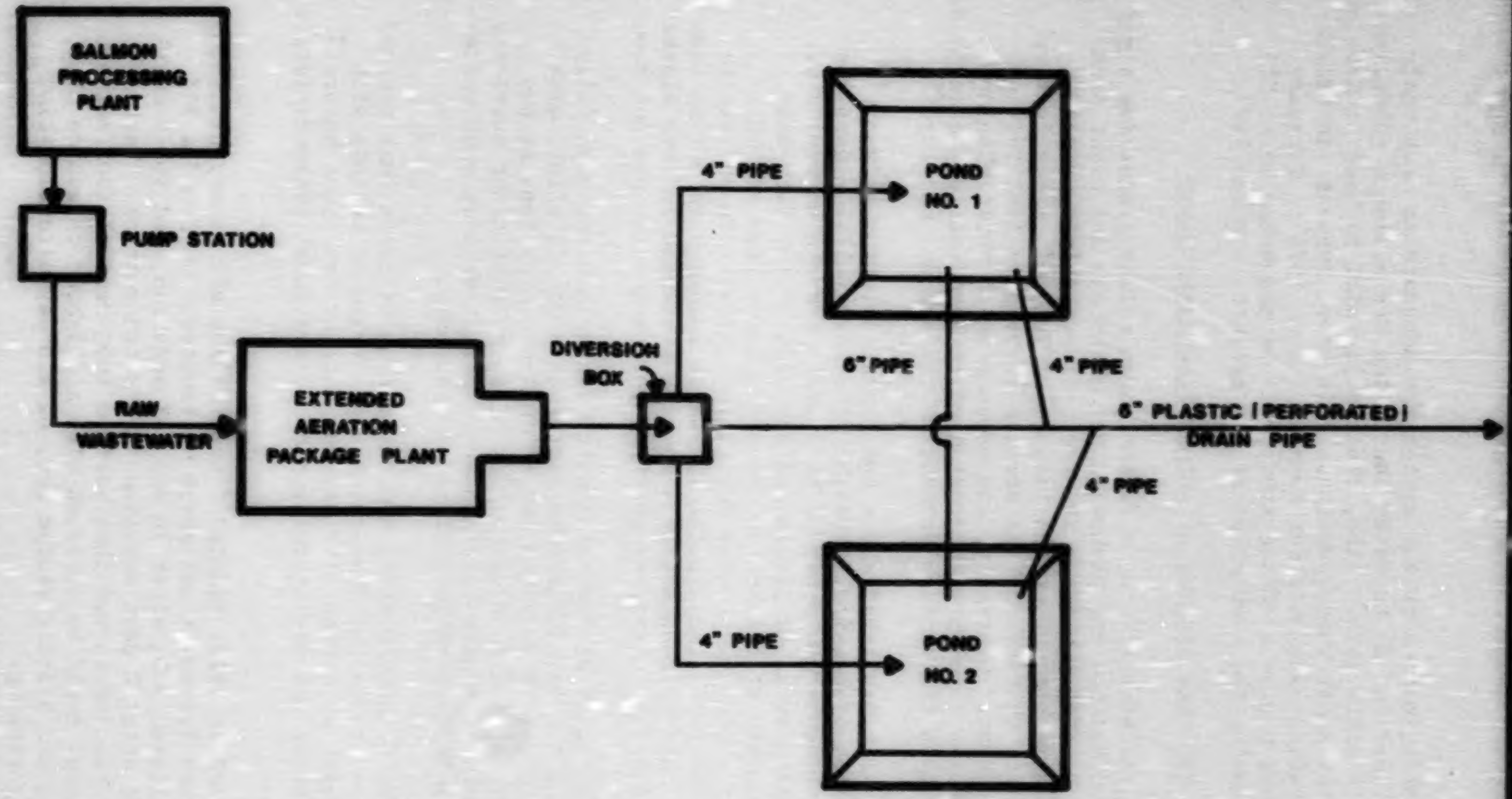

SALMON PROCESSING PLANT
PUMP STATION
RAW WASTEWATER
EXTENDED AERATION PACKAGE PLANT
DIVERSION BOX
4" PIPE
POND NO. 1
6" PIPE
4" PIPE
6" PLASTIC (PERFORATED) DRAIN PIPE
4" PIPE
4" PIPE
POND NO. 2

FIGURE 3. FLOW SCHEME OF THE WASTE TREATMENT SYSTEM SKOKOMISH PROCESSING PLANT SHELTON, WASHINGTON

if the control efficiencies of the system are adequate to meet waste effluent limitations and 2) to determine if the EPA effluent guidelines are realistically achievable. Also, the results will be used to develop engineering criteria for future design. This paper presents an evaluation of the operation data obtained from September 1975 to February 1976. An evaluation of the entire study will be presented in an EPA publication following the completion of the project in March 1977.

CHARACTERISTICS AND TREATABILITY OF SALMON PROCESSING WASTE

Only the wastewater generated at a fresh-frozen salmon processing plant will be discussed because the Skokomish salmon processing plant does not include the canning process. The fresh-frozen salmon process is essentially the same throughout the industry. The only major factors affecting the waste characteristics are the geographic location and the size of the plant. Generally, the processing of Pacific salmon as a fresh or frozen commodity is considered to have smaller waste loads and waste flows than the canning segment of the salmon industry.(1)

Very little has been published about the characteristics of waste generated by salmon processing. Possibly the most reliable data for salmon-processing waste was provided by a seafood-waste survey(1) of six plants in three areas of Alaska and one area of the Northwest. Table 2 lists summary statistics of the waste loads from all hand-butchered salmon processes studied during the survey. These results can be used to determine the typical raw-waste loadings resulting from fresh-frozen or hand-butchered salmon-canning processes in both Alaska and the West Coast when characteristics of the wastewater are not known.

Biological treatment of seafood-processing wastes has not been fully practiced in U.S. seafood industries except at a small, pilot, blue crab processing plant in Maryland and at full-scale systems at two shrimp processing plants in Florida.(1) However, sufficient nutrients are available in most seafood wastewaters, indicating that such wastewaters are amenable to aerobic biological treatment.

The Federal Water Quality Control Administration believes that seafood wastewater can be treated by domestic sewage-treatment methods with some waste strength adjustment.(2) In the Current Practices Report(3) the need for testing and developing optimum operational characteristics is outlined.

In a report issued in 1972, Riddle(7) studied the efficiency of biological systems for smelt and perch wastewater. He found a 90% removal of unfiltered BOD_5 after 10 days of aeration, and 90% removal of filtered BOD_5 after 2 days aeration in a batch reactor. Tests in a continuous reactor showed that maximum BOD_5 removal (80% soluble and 45% unfiltered) could be achieved with a 7.5-hour detention time, sludge recycling and a 3-day sludge age, or a 5-day detention time with no sludge recycling.

TABLE 2. HAND-BUTCHERED SALMON PROCESS SUMMARY*

Parameter	Mean	Std. Dev.	5% Min.	95% Max.
Production, ton/hr	2.13	1.09	0.733	4.38
Process Time, hr/day	6.34	1.80	3.67	8.98
Flow, l/sec	2.15	1.09	0.754	4.39
(gal/min)	34.1	17.2	11.9	77.5
Flow Ratio, l/kkg	5,040	3,100	1,410	13,000
(gal/ton)	1,210	743	338	3,120
Sett. Solids, ml/l	1.02	1.19	0.109	4.18
Ratio, l/kkg	5.15	5.99	0.547	20.5
Sol. Solids, mg/l	193	155	37.5	600
Ratio, kg/kkg	0.971	0.782	0.189	3.12
Sus. Solids, mg/l	236	185	47.6	722
Ratio, kg/kkg	1.19	0.933	0.240	3.54
5-Day BOD, mg/l	493	179	233	923
Ratio, kg/kkg	2.48	0.900	1.17	4.35
COD, mg/l	1,070	601	332	2,600
Ratio, kg/kkg	5.36	3.03	1.67	13.1
Grease/Oil, mg/l	341	628	15.0	1,770
Ratio, kg/kkg	1.72	3.16	0.076	8.39
Organic-N, mg/l	80.9	40.0	29.0	181
Ragio, kg/kkg	0.407	0.202	0.146	0.314
Ammonia-N, mg/l	2.12	0.794	0.979	4.14
Ratio, kg/kkg	0.011	0.004	0.005	0.120
pH	6.73	0.318	6.25	7.13
Temp., Deg. C.	13.2	2.51	9.19	15.7

*From Environmental Associates, Inc., ''Draft - Canned and Preserved Fish and Seafoods Processing Industry,'' February 1974.

In a later study, Robbins(1) reported that an activated-sludge plant in Japan has been designed especially for fish-waste treatment. The wastewater flow is approximately 0.27 mgd, and the 5-day BOD concentration ranges from 1,000 to 1,900 mg/l. The results of pilot-plant studies using a 10-hour aeration time, and the organic and hydraulic loadings, are listed in Table 3. Bulking occurred when the organic loading rate exceeded 0.31 lb/cu ft/day.

TABLE 3. ACTIVATED SLUDGE PLANT RESULTS*
FISH PROCESSING WASTES

Parameter	Raw Waste	BOD Loading (lb/cu ft/day)			
		0.075	0.14	0.21	0.26
BOD_5 (mg/l)	1,000	5	10	13	27
% Removal	-	99.5	99.0	98.7	97.3

*Obtained from Environmental Associates, Inc., ''Draft - Canned and Preserved Fish and Seafoods Processing Industry,'' February 1974.

The EPA effluent limitations guidelines for salmon processing plants are presented in Table 4. Based upon the weight of fish processed, the recommended effluent limitations for each processing plant can then be determined.

TABLE 4. RECOMMENDED EFFLUENT LIMITATIONS GUIDELINES FOR SALMON PROCESSING PLANTS(1)

Parameter	Maximum 30-Day Average (kg/kkg)	Maximum 30-Day Average (lb/ton)
5-Day BOD	3.2	6.4
Total Suspended Solids	2.0	4.0
Grease and Oil	4.9	9.8

*Only for West Coast hand-butchered salmon.

METHODS

Operation

Various operational conditions at the Skokomish salmon-processing waste-treatment facility are examined in this report and are summarized in the following paragraphs.

1. Test Schemes

Two test schemes for the study are depicted in Figure 4. Scheme A indicates that extended aeration and aerobic ponds are in series, but the aerobic ponds are in parallel. Similarly, Scheme B shows that extended aeration and two aerobic ponds are in series.

2. Extended Aeration System

Two major parameters, dissolved oxygen (DO) content and food-to-microorganism (F/M) ratio in the aeration tank, can be controlled during the study period. The DO content can be varied by adjusting impeller immersion. The F/M ratio (BOD/MLVSS) can be varied by adjusting MLVSS (mixed liquor volatile suspended solids) concentration, which is controlled by regulating the sludge recycling rate and the quantity of sludge wasted.

3. Aerobic Ponds

Two aerobic ponds are used to polish the effluent out of the extended aeration system. Surface area and retention time are the key factors affecting treatment efficiencies of aerobic ponds. Both factors can be varied by adjusting water depth.

Sampling

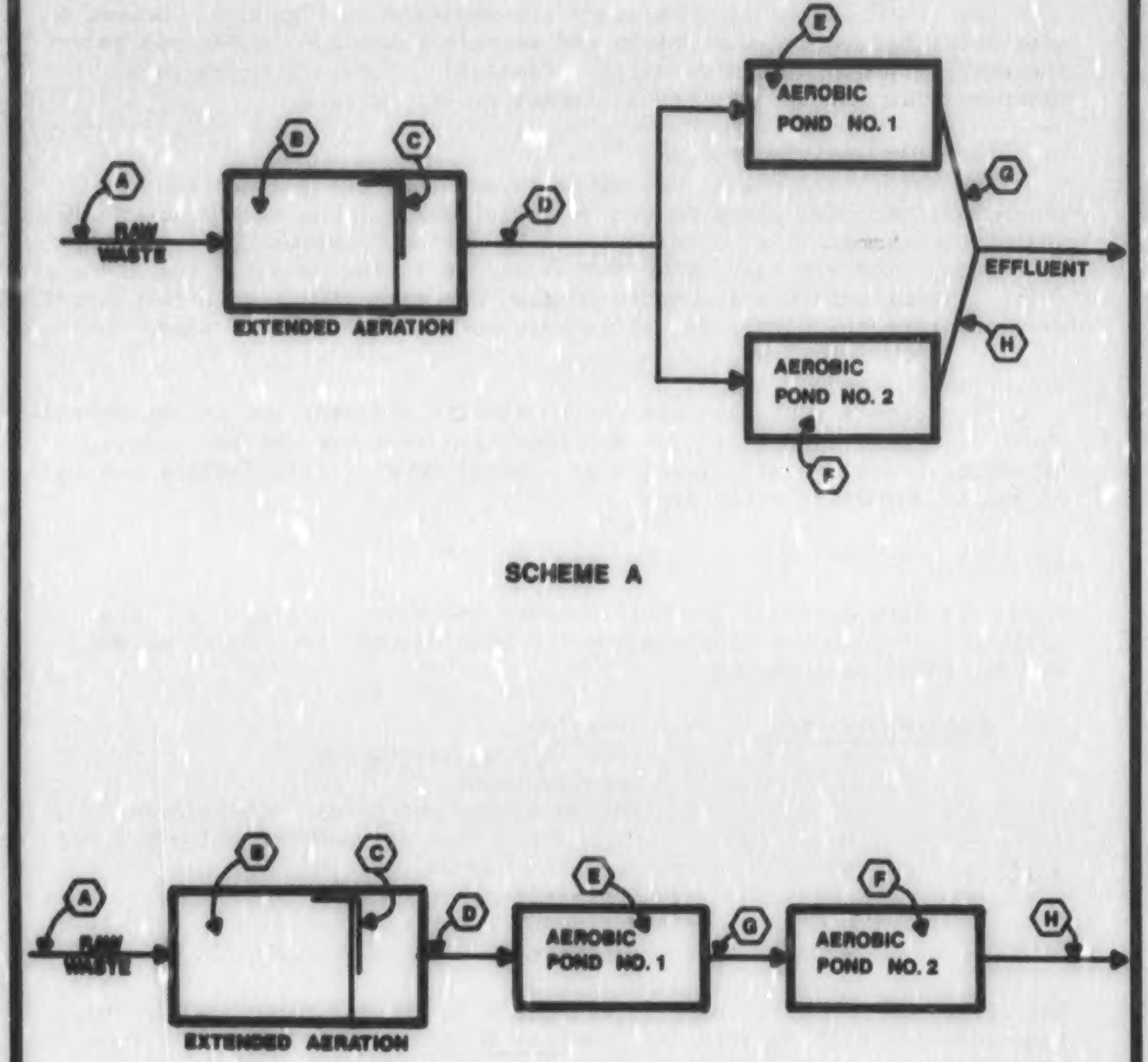
Eight sampling stations for both schemes are shown in Figure 4. The locations of each sampling station for both schemes are identical and are described as follows:

Sampling Stations	Location
a	Incoming raw wastewater
b	Aeration tank
c	Return sludge and excess sludge pipe
d	Effluent of the extended aeration process
e	Aerobic Pond No. 1
f	Aerobic Pond No. 2
g	Effluent of Aerobic Pond No. 1
h	Effluent of Aerobic Pond No. 2

Both grab and composite samples collected in the field were preserved in accordance with Methods for Chemical Analysis of Water and Wastes.(9) The daily and weekly sampling schedules are shown in Tables 5 and 6, respectively. The operational schedule for the entire study is presented in the Detailed Project Plan, which was submitted to the U.S. Environmental Protection Agency in July 1975.

Testing

All chemical and biological tests were analyzed in accordance with Standard Methods.(8) Field tests included flow measurement, pH, DO, and temperature. Laboratory tests conducted in the KCM Laboratory were BOD, COD, SS, VSS, TS, grease and oil, TKN, alkalinity, turbidity, ortho-P, total-P, MLSS and MLVSS.


A
RAW WASTE
B
C
EXTENDED AERATION
D
E
AEROBIC POND NO. 1
G
EFFLUENT
H
AEROBIC POND NO. 2
F
SCHEME A
A
RAW WASTE
B
C
EXTENDED AERATION
D
E
AEROBIC POND NO. 1
G
F
AEROBIC POND NO. 2
H

SCHEME B

FIGURE 4 PROCESS LAYOUTS.

TABLE 5. DAILY SAMPLING SCHEDULE

Sampling Stations	Sampling Frequency	Tests
a	Grab Samples/2 hour	Flow, Temp, pH, DO
	Eight-hour Composite Sample	BOD, COD, SS, VSS, TS, Grease/Oil*, TKN, Ortho-P, Total-P, Alaklinity, Turbidity
b	One Grab Sample Daily	MLSS, MLVSS, DO, Alk., pH, Temp.
c	One Grab Sample Daily	SS, VSS, Flow
d	Same as (a)	Same as (a) (Flow measurement is not necessary)
e	One Grab Sample Daily	DO, pH, Temp.
f	Same as (e)	Same as (e)
g	Same as (d)	Same as (d)
h	Same as (d)	Same as (d)

*One grab sample for sampling day.

TABLE 6. WEEKLY SAMPLING SCHEDULE

Week	Monday	Tuesday	Wednesday	Thursday	Friday
1st	S		S		
2nd		S			
3rd			S		S
4th				S	

Note: S indicates the day for sampling.

It should be noted that this paper serves as an interim report since the entire testing schedule has not been completed. Due to the low flow entering the treatment facility, only one aerobic pond was in operation during this phase of the study. Because of the small quantity of extended aeration effluent reaching the pond and pond seepage, sampling at Stations E through H has not commenced. This paper emphasizes the evaluation of the operation of an extended aeration system. However, the operation of aerobic ponds also will be evaluated as the project progresses.

RESULTS AND DISCUSSION

The aeration tank of the extended aeration system was seeded before the monitoring program was started in the beginning of September 1975. One thousand gallons of returned activated sludge with a suspended solids concentration of approximately 4,500 mg/l was obtained from the Renton Treatment Plant, Renton, Washington, and fed into the aeration tank for seeding.

Water meters were installed for continuous recording of water consumption during fish processing. The used water was then pumped to the extended aeration system for treatment. Water utilized for sanitary purposes was transported into a septic tank for treatment. The duration of each pumping period also was recorded. Using pumping duration and rate, the flow rate entering the treatment system was then computed. In order to record flow rate between the extended aeration system and the aerobic pond, a weir box was installed in a corner of the aerobic pond. Flow rate was computed from a continuous record of the depth of wastewater over the V-notch in the weir box. Wastewater generated from fish processing was screened by a fine screen installed in the drain entering the pump station.

As indicated previously, this paper presents the evaluation of operational data obtained only from September 1975 to February 1976. The intent of this portion of the study period was to monitor the performance of the extended aeration system with a minimum control. The daily operational conditions during this five-month period are discussed in the following.

The monitoring program was started on September 12, 1975, but composite sampling was not taken until September 17, 1975. Large salmon were processed from September 12 to December 5, 1975. Large salmon herein refers to an average weight of 10 pounds per salmon. Due to the unexpected difficulty in obtaining fish for processing, no fresh fish were processed from December 6, 1975 to January 30, 1976. Repacking frozen fish, which produced no wastewater, was the only activity occurring during that interval.

In order to maintain the performance of waste-treatment systems during the time fish-processing wastes were unavailable, Purina Trout Chow was fed into the treatment system. This fish food was added from January 16, 1975 to January 30, 1976. Approximately 9.5 pounds of fish food were dissolved into 560 gallons of water, and the solution was then fed into the pump station.

Processing of fresh fish was resumed on February 2, 1976, when small salmon became available. The processing of small salmon is expected to continue for several more months. Small salmon herein refers to an average weight of 11 ounces per fish. Variations which affected wastewater production during this period are summarized as follows:

Intervals	Processing Activities
9/12/75 to 12/5/75	Large salmon
12/6/75 to 1/15/76	No activity except repacking
1/16/76 to 1/30/76	Fish food addition
2/2/76 to 2/29/76	Small salmon

The following presents the results of different processing activities during the five-month study period.

Wastewater Characteristics

The characteristics of wastewater generated from the salmon processing plant varied daily. An attempt was made to correlate the waste flow and pollutant strength with total weight of fish processed. In order to generalize and reflect the fluctuation of operational data, average, standard deviation and ranges were utilized. Wastewater characteristics for large salmon processing, small salmon processing and fish food addition are summarized in Tables 7, 8 and 9, respectively.

It can be seen that wastewater characteristics during fish food addition were comparable to those during salmon processing, and the performance of the treatment system was maintained when receiving no fresh-fish processing wastewater. Approximately 20% of total weight of fish processed was wasted. The wastage has been hauled away to sanitary landfill for disposal. Comparison of Tables 7 and 8 indicates that flow and pollutants generated per ton of fish processed for small salmon is greater than that for large salmon. In other words, less flow and fewer pollutants were generated during large-salmon processing.

High variations of wastewater characteristics were reflected in high ratios of standard deviation to average. It is believed that the fluctuation of wastewater characteristics may be reduced as more data become available.

Treatment Efficiencies

Similarly, average and standard deviation were used to present various treatment efficiencies for each parameter. Treatment efficiencies for wastewater produced by large salmon processing, small salmon processing and fish food addition are summarized in Tables 10, 11 and 12, respectively.

TABLE 7. WASTEWATER CHARACTERISTICS FOR LARGE SALMON PROCESSING

Parameter	Average	Standard Deviation	Range
Flow, gpd	691	237	405–1,215
Process Time, hr/day	6.5	1.0	5.5–8.0
Fish Processed, lb/day	3,153	2,658	324–9,970
Processing Wastage, lb/day	747	614	188–1,733
Gallon of Wastewater per Ton of Fish Processed	723	599	240–2,500
Turbidity, JTU	100	49	24–205
pH	7.21	0.13	6.9–7.7
DO, mg/l	7.88	1.04	6.8–11.9
Temp., Deg. F.	51.5	3.6	38–58
Alk., mg/l as $CaCO_3$	128.5	88	10–388
BOD (total), mg/l	687	445	79–1,708
BOD (total), lb/ton	3.26	2.5	0.92–8.4
COD (total), mg/l	2,057	1,120	595–4,864
COD (total), lb/ton	10.51	8.6	2.64–34.14
BOD/COD (total), mg/l	0.328	0.105	0.133–0.546
BOD/COD (total), lb/ton	0.328	0.105	0.133–0.546
SS, mg/l	502	224	250–950
SS, lb/ton	2.5	1.38	0.83–6.25
VSS, mg/l	265	147	100–700
VSS, lb/ton	1.3	0.86	0.46–4.17
VSS/SS, mg/l	0.541	0.175	0.278–0.778
VSS/SS, lb/ton	0.541	0.175	0.278–0.778
TS, mg/l	1,638	861	575–2,525
TS, lb/ton	7.47	2.76	3.28–12.38
Grease and Oil, mg/l	283	142	24–541
Grease and Oil, lb/ton	1.46	0.93	0.078–3.53
TKN, mg/l	207	197	2–850
TKN, lb/ton	0.86	0.49	0.006–2.16
NH_4^+-N, mg/l	6.04	7.25	1.2–26
NH_4^+-N, lb/ton	0.0367	0.0434	0.0039–0.161
Total-P, mg/l	0.8	0.48	0.3–1.75
Total-P, lb/ton	0.0061	0.0083	0.0011–0.0271
Ortho-P, mg/l	0.34	0.16	0.1–0.6
Ortho-P, lb/ton	0.00212	0.0022	0.00024–0.00834

TABLE 8. WASTEWATER CHARACTERISTICS FOR SMALL SALMON PROCESSING

Parameter	Average	Standard Deviation	Range
Flow, gpd	3,631	959	2,044–5,154
Process Time, hr/day	5.4	1.3	4.0–8.0
Fish Processed, lb/day	2,557	472	1,520–3,500
Processing Wastage, lb/day	498	49	400–500
Gallon of Wastewater per Ton of Fish Processed	3,000	1,420	2,040–8,080
Turbidity, JTU	74	54	30–180
pH	7.23	0.12	7.1–7.4
DO, mg/l	6.93	2.20	4.0–11.3
Temp., Deg. F.	45.5	1.65	42–48
Alk., mg/l as $CaCO_3$	58.5	9.35	44–70
BOD (soluble), mg/l	452	103	335–528
BOD (soluble), lb/ton	9.5	2.8	7.24–12.57
COD (soluble), mg/l	626	146	521–793
COD (soluble), lb/ton	12.49	1.14	11.26–13.52
BOD/COD (soluble), mg/l	0.732	0.175	0.62–0.934
BOD/COD (soluble), lb/ton	0.732	0.175	0.62–0.934
BOD (total), mg/l	484	194	211–726
BOD (total), lb/ton	11.58	3.5	7.76–16.74
COD (total), mg/l	814	201	650–1,104
COD (total), lb/ton	21.18	9.49	13.57–39.50
BOD/COD (total), mg/l	0.581	0.153	0.36–0.81
BOD/COD (total), lb/ton	0.581	0.153	0.36–0.81
SS, mg/l	234	90	134–370
SS, lb/ton	6.53	4.51	2.90–14.83
VSS, mg/l	139	67	48–244
VSS, lb/ton	3.92	2.91	1.04–8.76
VSS/SS, mg/l	0.582	0.151	0.358–0.803
VSS/SS, lb/ton	0.582	0.582	0.358–0.803
TS, mg/l	888	230	600–1,155
TS, lb/ton	23.08	10.2	12.97–41.25
Grease and Oil, mg/l	177	55	96–260
Grease and Oil, lb/ton	4.34	1.19	3.11–6.47
TKN, mg/l	65	64	23–191
TKN, lb/ton	2.81	4.94	0.54–12.87
NH_4^+-N, mg/l	2.42	0.94	0.9–3.7
NH_4^+-N, lb/ton	0.077	0.064	0.015–0.202
Total-P, mg/l	1.84	0.74	1.2–2.9
Total-P, lb/ton	0.038	0.016	0.02–0.06
Ortho-P, mg/l	0.3	0.2	0.2–0.7
Ortho-P, lb/ton	0.0078	0.005	0.0034–0.0145

TABLE 9. WASTEWATER CHARACTERISTICS FOR FISH FOOD ADDITION

Parameter	Average	Standard Deviation	Range
Flow, gpd	1,022	1,017	550–2,841
Fish Food, lb/day	9.5	0	9.5–9.5
Turbidity, JTU	91.5	32.4	51.5–137
pH	6.9	0.217	6.7–7.2
Temp., Deg. F.	45	1.58	43–47
Alk., mg/l as $CaCO_3$	59	13.8	44–74
BOD (total), mg/l	400	56.8	319–458
COD (total), mg/l	688	131	551–833
BOD/COD (total), mg/l	0.587	0.064	0.540–0.698
SS, mg/l	354	134	160–485
VSS, mg/l	200	60.9	133–279
VSS/SS	0.652	0.355	0.300–1.25
TS, mg/l	525	219	250–775
Grease and Oil, mg/l	199	203	75–560
TKN, mg/l	99	10.6	82–110
NH_4^+-N, mg/l	2.48	0.80	1.7–3.8
Total-P, mg/l	1.46	0.39	0.8–1.8
Ortho-P, mg/l	0.33	0.12	0.2–0.5

TABLE 10. EXTENDED AERATION TREATMENT EFFICIENCIES FOR LARGE SALMON PROCESSING WASTEWATER

Parameter	Average	Standard Deviation	Range
DO, mg/l	8.3	1.4	6.2–10.2
Retention Time, days	31	8	16.4–49
pH	7.3	0.97	5.8–8.4
SVI	103	25	67–155
BOD/MLVSS	0.06	0.06	0.01–0.09
MLVSS/MLSS	516/978	174/218	225/525–850/1,300
Overflow Rate, gpd/ft^2	7.2	2.3	4.1–12.4
BOD, %	91	8	67–98
COD, %	88	5	75–96
SS, %	62	18	24–94
VSS, %	66	20	33–93
TS, %	45	19	10–74
Grease and Oil, %	69	19	25–91
TKN, %	83	16	48–99
NH4$^+$-N, %	72	24	8–95
Total-P, %	28	3	25–33
Ortho-P, %	37	25	0–75

TABLE 11. EXTENDED AERATION TREATMENT EFFICIENCIES FOR SMALL SALMON PROCESSING WASTEWATER

Parameter	Average	Standard Deviation	Range
DO, mg/1	9.2	1.6	7.9–10.9
Retention Time, days	6.2	2.1	3–9.8
pH	7.4	0.22	7.1–7.7
SVI	118	41	67–192
BOD/MLVSS	0.084	0.036	0.046–0.1414
MLVSS/MLSS	1029/1693	313/468	550/850–1400/2200
Overflow Rate, gpd/ft^2	36.5	13.8	20.9–62.7
BOD, %	86 (90)*	8 (7)*	79–98 (82-97)*
COD, %	83 (90)*	8 (5)*	67–91 (84-94)*
SS, %	63	30	5–84
VSS, %	54	29	6–80
TS, %	60	7	52–67
Grease and Oil, %	60	22	17–74
TKN, %	48	35	0–94
NH_4^+-N, %	52	35	4–62
Total-P, %	N/A†	N/A†	N/A†
Ortho-P, %	N/A†	N/A†	N/A†

*Soluble portion

†N/A indicates that effluent concentrations were either greater than or equal to influent

TABLE 12. EXTENDED AERATION TREATMENT EFFICIENCIES DURING FISH FOOD ADDITION

Parameter	Average	Standard Deviation	Range
DO, mg/1	9.7	1.4	7.6–10.2
Retention Time, days	29.6	12.7	7.0–36.4
pH	7.4	0.26	7.1–7.7
SVI	97	47	111–133
BOD/MLVSS	0.039	0.039	0.015–0.108
MLVSS/MLSS	540/1306	114/93	400/1200–700/1400
Overflow Rate, gpd/ft^2	10.6	10.8	5.6–30.0
BOD, %	88	7	76–97
COD, %	85	6	77–91
SS, %	78	12	64–93
VSS, %	75	6	67–81
TS, %	54	10	43–67
Grease and Oil, %	61	16	47–88
TKN, %	92	0.5	92–93
NH_4^+-N, %	21	17	0–38
Total-P, %	N/A†	N/A†	N/A†
Ortho-P, %	7	N/A†	0–20

†N/A indicates that effluent concentrations were either greater than or equal to influent

Lower ratios of standard deviation to average indicated that treatment efficiencies were comparably consistent. Low wastewater generated from the processing plants resulted in longer retention time, high dissolved oxygen content and lower overflow rate. It is anticipated that these operation conditions will improve when more fish are being processed. The treatment efficiencies during fish food addition were comparable to those during salmon processing. This finding demonstrated that the addition of fish food could maintain the performance of the treatment system when no salmon processing wastewater was available.

Average BOD removal efficiencies were more than 85%, which is within the range for a biological secondary-treatment system. However, removal efficiencies for SS were less than 70%, indicating the poor settleability of solids in the clarifier. Poor settleability of solids (SS, VSS, and TS) resulted from longer retention time and overaeration. The removal efficiency of SS could be improved with the increase in wastewater flow.

Both ortho and total phosphorus contents in the effluent were either greater than or equal to those for the influent during most of the five-month study period. This could be due to overaeration resulting from longer retention time. It was reported(10) that extended aeration resulted in the depletion of carbon source, which is very likely to cause the release of phosphorus in the aeration tank. Shorter retention time would certainly minimize the problem.

Oxygen Uptake Rate

Oxygen uptake for mixed liquor suspended solids was tested in the field by using a YSI DO probe. The oxygen uptake rates for different dates were computed and tabulated. Only the summary of the test results is presented below.

Average	1.56 mg/l/hr
Standard Deviation	0.92 mg/l/hr
Range	0.5–4.2 mg/l/hr

No conclusion could be drawn based upon the available data. More tests should be conducted as the project progresses in order to correlate oxygen uptake rate with retention time, BOD/MLVSS, etc.

Sludge Filterability

Sludge disposal is an important factor in the operation of wastewater treatment systems. So far, no sludge has been wasted. To facilitate analytical work, a sludge filterability test was conducted to indicate sludge characteristics. One hundred milliliters (100 ml) of sludge was filtered under a pressure of 21 psi for 80 minutes, and solid concentrations were measured at 0, 20, 40, 60 and 80 minutes. For this study, an attempt was made to compare the percent of SS increase to that obtained from conventional activated-sludge process treating of domestic wastewater.(11) The comparison, as shown below, demonstrated that sludge filterability for the Skokomish study was similar to that for conventional activated sludge. More data will be compiled as the project progresses to substantiate this finding.

	Filtering Pressure (psi)	Time (min)	Percentage of SS Increase
Skokomish Study	21	20	495
Activated Sludge	5	20	115

EPA Effluent Limitations

Effluent quality in terms of BOD, SS and grease and oil was checked against the recommended EPA effluent limitations.(1) Comparison of extended aeration effluent quality with EPA effluent limitations is shown in Table 13. It can be seen that effluent quality of extended aeration met all the recommended limitations. Based upon available results, it can be concluded that the system is capable of meeting EPA effluent limitations.

TABLE 13. COMPARISON OF EXTENDED AERATION EFFLUENT QUALITY WITH EPA EFFLUENT LIMITATIONS

	Average Weight of Fish Processed (lb/day)	EPA Effluent Limitations (lb/day)	Extended Aeration Effluent Quality (lb/day)	
			Average	Range
Large Salmon				
BOD, lb/day	3,153	10.1	0.4	0.03–1.3
SS, lb/day	3,153	6.3	1.5	0.3–3.0
Grease and Oil, lb/day	3,153	14.7	0.7	0.1–1.2
Small Salmon				
BOD, lb/day	2,557	8.2	2.1	0.2–3.5
SS, lb/day	2,557	5.1	3.1	0.6–10.7
Grease and Oil, lb/day	2,557	15.4	2.2	1.1–4.1

CONCLUSIONS

From the results obtained during the five-month study period, the following conclusions may be made:

1. Small salmon processing generates more wastewater flow and higher pollutant contents per unit of fish processed than does large salmon processing.

2. Fish food addition was found capable of maintaining performance of the wastewater treatment system when no wastewater was received from the salmon processing plant.

3. Both longer retention time and overaeration result in poor settleability in the clarifier and release of phosphorus in the aeration tank. The latter consequently causes a high phosphorus content in the effluent.

4. Sludge filterability for the extended aeration system was found similar to that for conventional activated sludge.

5. The treatment system is capable of producing an effluent which meets the EPA effluent limitations in terms of BOD, SS, and grease and oil.

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RECLAMATION AND TREATMENT OF CLAM WASH WATER

by

R. R. Zall*, L. F. Hood*, W. J. Jewell**,
R. L. Conway*, and M. S. Switzenbaum**

INTRODUCTION

The surf clam is a relatively recent addition to the Atlantic Coast shellfish processing industry. The major industry growth occurred in the mid 1940's and in 1958, when new offshore beds near Long Island were discovered. Animal presence, coupled with improved harvesting methods, brought about substantial increases to seafood production in New York State marine fisheries. Today annual amounts of surf clam meats from New York approximate 2,000 metric tons of finished product or about 7% of the total landings in the United States.

When growth occurs and plants enlarge to handle increased volumes, waste generated from food processing activities becomes troublesome and difficult to handle. The organic material wasted from clam processing sites place a burden on sewage systems. If discharged without treatment, it probably pollutes waters near the Coast where these types of plants operate.

Research Objectives and Plan

A team of professors and graduate students from the Department of Food Science and Agricultural Engineering at Cornell University have been studying the reclamation of protein and flavor material from clam wash water. The purpose of the project was to assist the clam processing industry in developing methods to create salable products from sewage where the economics of waste handling might be turned into a credit rather than debit to the industry.

After studying the problems at a single site, the Cornell group drew up a research plan with the following objectives:

(1) Develop process flows to reduce water consumption and BOD discharge loads.

(2) Develop edible products from proteins and flavor materials in clam mincing wash water.

(3) Develop methods that a seafood processing plant might use to reduce the costs of sewage disposal.

(4) Define composition of the solids and flavor components in wash water together with chemical reactions responsible for flavor deterioration in wash waters.

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*Department of Food Science, Cornell University, Ithaca, New York
**Department of Agricultural Engineering, Cornell University, Ithaca, New York

This paper summarizes one phase of the study and partially reports the progress of the ongoing project.

A Single Site Study

The research group formed an affiliation with a well-known Long Island surf clam processing company. During 1975, five multi-day trips were made to the plant in January, February, May, July, and November for the purpose of obtaining samples and observing plant operations. In between periods were utilized for evaluation of site sampling materials in laboratories and pilot plants at Cornell's Ithaca campus.

The thrust of our work was to:

(1) Fully understand plant operations in order to recommend sound production changes to reduce water consumption.

(2) Determine if seasonal variations occur in the chemical and microbiological properties of wash water and clam products.

(3) Conduct a bench top waste treatment study of waste flows generated from plant operations.

(4) Use different processing methods to treat rinse waters with existing plant equipment and with experimental equipment moved from Ithaca to Long Island.

Mode of Operations

The plant is one of the twelve clam processing plants in the New York-New Jersey-Maryland area. It is located on eastern Long Island and faces a small harbor on two sides. The site occupies a land area of approximately 1.5 acres. The processing building, refrigerated storage, ice making sheds, and garages are located on the site. Loading and unloading areas are strategically placed to handle raw receipts and shipments of finished goods.

A flow chart of plant operations is shown in Figure 1. Surf clams are delivered to the plant by truck and transferred to refrigerated storage in 32-bushel capacity tote bins until utilized.

At processing time, tote bins are moved with forklift trucks to the dumping table where the clams are dumped into a 190°F water tank and held for about one minute. This operation removes surface silt and a black membrane above the opening of the clam shell. In addition, the hot wash makes the clam easier to handle by the shuckers. Incoming clams are transferred by belt conveyor to a shucking station where up to 30 people open shells and harvest clam meats. At this point shells and bellies are separated from edible clam meats and sent to waste on an out-of-plant discharge belt conveying system.

Waste portions are separated outside the building into different fractions like bellies and shells which are then disposed of via dump truck, garbage

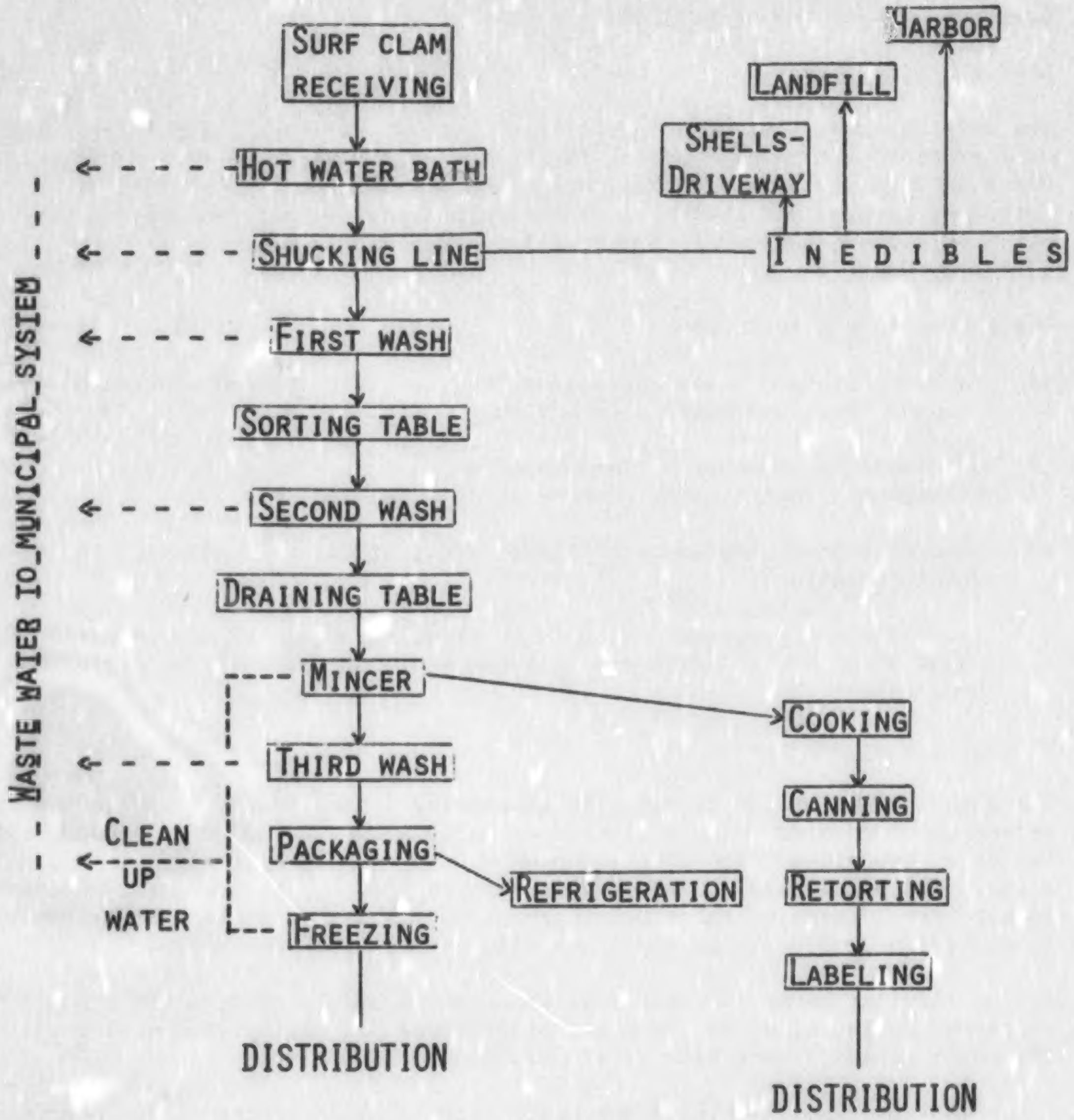
SURF CLAM RECEIVING
HOT WATER BATH
SHUCKING LINE
FIRST WASH
SORTING TABLE
SECOND WASH
DRAINING TABLE
MINCER
THIRD WASH
PACKAGING
FREEZING
DISTRIBUTION
WASTE WATER TO MUNICIPAL SYSTEM
CLEAN UP WATER
REFRIGERATION
HARBOR
LANDFILL
SHELLS-DRIVEWAY
INEDIBLES
COOKING
CANNING
RETORTING
LABELING
DISTRIBUTION

Figure 1. Flow Diagram of Surf Clam Processing.

boat, or direct to the harbor.

The clam meat is taken by the shucker via gallon buckets to a dump table in a wash area where the material is washed by a mechanical spray-cleaning rotating chamber (Station 1).

At first glance, the shucking process may seem somewhat primitive, but it is a workable method by which a shucker is graded and compensated for individual productivity.

Rinsed meat is manually sorted on a slow moving belt by several inspectors at a second table and washed again through a second stainless steel spray-tumbling device similar to the Station 1 washer.

At this point, washed clams are transferred via plastic pails to a mincer device that resembles a large meat grinder but without cutting knives in the discharge port. Mincing is supposed to take out the last residues of sand and tenderize the meat (Station 3).

From this point, meat is either packed for fresh sales, frozen in trays for frozen sales, or cooked in broth for canning purposes as shown in Figure 1.

Broth is made in steam kettles and then canned. Filled cans are further processed in retorts, cooled, marked, and cased for truck load shipments to sales outlets.

Water Usage and Waste

The plant uses potable water obtained from a town water system and returns all liquid wastes to a municipal waste treatment plant system. Water cost is 40¢/1,000 gallons plus 48¢/1,000 gallons for waste treatment services.

About 30,000-40,000 gallons of water per day are used in the plant to process approximately 500 bushels of surf clams. Historically, the company operates around 270 days per year and currently spends $8,000-9,000 per year for water and sewage utilities.

Water usage and waste basically occur at the three washing locations and are identified in this paper as Stations 1, 2, and 3.

Tables 1 and 2 show the flow rates, which vary only slightly from day to day.

Daily water usage was monitored on different operating days, and typical data are shown in Table 2.

TABLE 1. FLOW RATES AT WASHING STATIONS

Station	Rate	Where measured
	(gal/min)	
1	60	Outside settling basin
2	10	Copper drain pipe from bath
3	5	Outside settling tank

TABLE 2. DAILY WATER USAGE

	Water usage		
Time	1/8/75	2/10/75	2/11/75
	----------gal----------		
7- 9 a.m.	12,000	11,850	12,000
9-10 a.m.	5,900	3.200	2.900
10-11 a.m.	5,000	4,000	4,900
11-12 a.m.	4,300	6,000	3,800
12- 1 p.m.	2,000	2,000	2,400
1- 2 p.m.	5,300	5,000	4,200
2- 3 p.m.	4,900	5,100	4,800
3- 4 p.m.	2,800	900	4,400
Total/day	38,200	38,050	39,400

Wastewater Characteristics

Wastewater was sampled at hourly intervals during operating days. Composite samples of each station were prepared from individual hourly samples based upon flow rates so as to form a representative sampling picture of the day's actual operations.

Tables 3, 4, 5, and 6 show pertinent biological-chemical data needed by our group to help evaluate the relative food values of these waste flows.

TABLE 3. BOD AND COD ANALYSIS OF COMPOSITES FROM WASHING STATIONS FEBRUARY 1975

Station	BOD	COD
	------mg/1------	
1	234	680
2	558	937
3	2340	-

TABLE 4. PROTEIN AND SOLIDS CONTENT OF HOURLY SAMPLES OF WASH WATER FROM STATION 3 - FEBRUARY AND MAY 1975

	Protein		Total solids		Protein as % of total solids	
Sample time	February	May	February	May	February	May
	----------	----------	----------	%	----------	----------
9:00 a.m.	-[a]	0.69	-	1.4	-	49
9:30 a.m.	0.17	-	0.73	-	23	-
10:00 a.m.	0.11	0.46	0.60	1.0	18	46
10:30 a.m.	0.24	-	0.65	-	37	-
11:00 a.m.	0.36	0.51	0.86	1.2	42	42
11:30 a.m.	0.14	0.42	0.97	0.9	14	46
1:00 p.m.	0.08	-	0.22	-	36	-
1:30 p.m.	0.06	0.08	0.23	0.3	26	28
2:00 p.m.	0.10	0.36	0.41	0.7	24	51
2:30 p.m.	0.10	-	0.35	-	29	-
3:00 p.m.	0.06	0.30	0.31	0.4	19	76
3:30 p.m.	0.09	0.36	0.58	0.6	16	60

[a] - = no sample drawn at this time

TABLE 5. PROTEIN AND TOTAL SOLIDS IN COMPOSITE SAMPLES OF WASH WATER

Station	Month	Protein	Total solids	Protein as % of total solids
			%	
1	January	0.15	0.08	
	February	0.06	0.08	77
2	January	0.16	0.74	22
	February	0.09	0.35	41
3	January	1.07	1.70	63
	February	0.33	0.33	94

TABLE 6. CALCIUM, PHOSPHORUS, AND CHLORIDE CONCENTRATIONS IN COMPOSITE SAMPLES OF CLAM WASH WATER

Station	Month	Calcium	Phosphorus	Chloride
			/ml	
1	January	60	6	207
	February	65	40	6
2	January	57	26	280
	February	61	62	7
3	January	72	230	540
	February	44	109	7

Microbial Quality of Clam Meat and Wash Water

The possibility of seasonal variations in wash water quality seemed probable with changes in water temperature. In order to learn what these effects might be, the following data were collected.

Tables 7, 8, and 9 show typical bacteriological data of the wash water and clam meat during different seasons at the final station before packaging or cooking.

TABLE 7. STANDARD PLATE COUNT OF CLAM AND WASH WATER AT STATION #

Sample type	Time drawn	Month of sampling			
		February	May	July	November
		#/ml			
Wash water	8:30 a.m.	-[a]	480,000	107,000	242,000
	9:30 a.m.	14,000	162,000	86,000	167,000
	10:30 a.m.	32,000	472,000	83,000	200,000
	11:30 a.m.	60,000	640,000	94,000	125,000
	2:00 p.m.	-	1,420,000	109,000	-
	3:00 p.m.	-	930,000	98,000	-
		#/g			
Clam surface	8:30 a.m.	-	10,000,000	204,000	395,000
	9:30 a.m.	28,000	7,000,000	188,000	1,300,000
	10:30 a.m.	130,000	7,000,000	153,000	228,000
	11:30 a.m.	50,000	4,000,000	192,000	152,000
	2:00 p.m.	-	9,000,000	191,000	-
	3:00 p.m.	-	5,000,000	167,000	-
		#/g			
Meat ground in sterile water	8:30 a.m.	-	8,000,000	101,000	340,000
	9:30 a.m.	10,000	3,000,000	128,000	550,000
	10:30 a.m.	32,000	6,000,000	76,000	76,000
	11:30 a.m.	18,000	4,000,000	131,000	176,000
	2:00 p.m.	-	9,000,000	127,000	-
	3:00 p.m.	-	5,000,000	72,000	-
		#/ml			
Clam solids, washed with sterile water	8:30 a.m.	-	4,000,000	42,000	18,000
	9:30 a.m.	6,300	1,000,000	42,000	42,000
	10:30 a.m.	18,000	300,000	29,000	43,000
	11:30 a.m.	13,000	220,000	33,300	61,000
	2:00 p.m.	-	370,000	12,000	-
	3:00 p.m.	-	101,000	14,700	-

[a] - = no sample drawn at this time

TABLE 8. COLIFORM COUNT OF CLAM AND WASH WATER AT STATION 3

Sample type	Time drawn	Month of sampling			
		February	May	July	November
		#/ml			
Wash water	8:30 a.m.	–[a]	269	90	153
	9:30 a.m.	10	23	80	67
	10:30 a.m.	70	24	70	33
	11:30 a.m.	80	12	40	97
	2:00 p.m.	–	47	60	–
	3:00 p.m.	–	32	70	–
		#/g			
Clam surface	8:30 a.m.	–	248	160	100
	9:30 a.m.	20	70	20	90
	10:30 a.m.	50	309	100	70
	11:30 a.m.	20	42	90	50
	2:00 p.m.	–	13	30	–
	3:00 p.m.	–	43	10	–
		#/g			
Meat ground in sterile water	8:30 a.m.	–	237	20	10
	9:30 a.m.	10	62	40	0
	10:30 a.m.	10	167	30	0
	11:30 a.m.	10	20	10	20
	2:00 p.m.	–	20	10	–
	3:00 p.m.	–	38	10	–
		#/ml			
Clam solids, washed with sterile water	8:30 a.m.	–	33	30	0
	9:30 a.m.	10	17	0	10
	10:30 a.m.	10	43	130	10
	11:30 a.m.	20	15	50	20
	2:00 p.m.	–	12	30	–
	3:00 p.m.	–	8	30	–

[a] – = no sample drawn at this time

TABLE 9. YEAST AND MOLD COUNT OF CLAM AND WASH WATER AT STATION 3

		Month of sampling			
Sample type	Time drawn	February	May	July	November
		#/ml			
Wash water	8:30 a.m.	–[a]	8	460	170
	9:30 a.m.	20	2	420	225
	10:30 a.m.	20	6	290	251
	11:30 a.m.	30	192	570	44
	2:00 p.m.	–	183	490	–
	3:00 p.m.	–	108	390	–
		#/g			
Clam surface	8:30 a.m.	–	25	540	350
	9:30 a.m.	10	30	400	620
	10:30 a.m.	10	7	590	210
	11:30 a.m.	10	13	630	200
	2:00 p.m.	–	16	520	–
	3:00 p.m.	–	16	480	–
		#/g			
Meat ground in sterile water	8:30 a.m.	–	23	370	20
	9:30 a.m.	10	28	290	20
	10:30 a.m.	10	14	170	30
	11:30 a.m.	10	12	320	115
	2:00 p.m.	–	26	120	–
	3:00 p.m.	–	14	200	–
		#/ml			
Clam solids, washed with sterile water	8:30 a.m.	–	16	420	90
	9:30 a.m.	20	7	210	80
	10:30 a.m.	10	5	200	30
	11:30 a.m.	10	10	370	40
	2:00 p.m.	–	14	470	–
	3:00 p.m.	–	11	320	–

[a] – = no sample drawn at this time

Besides looking at the wash water and the clam surface, the tables also give microbiological counts of meat washed with sterile water and then meat ground in sterile water. The purpose of the analysis was to see if microorganisms penetrated the meat interiors.

Table 10 shows that potable water temperature varies from 40° - 68°F.

TABLE 10. SEASONAL CHANGES IN WATER TEMPERATURE AT PLANT

Month	Temperature (°F)
January	48
February	46
May	62
July	68
November	56

CONVERSION OF WASH WATER TO A CANNED JUICE PRODUCT

The research team trained itself to evaluate the flavor components in Station 3 wash water. Preliminary tasting sessions were used to identify flavor characteristics peculiar to clam wash water. Comments such as fishy, bitter, astringent, unclean, and musty were noted. (See Figures 2 and 3.)

The clam juice product being marketed by the firm was used as the reference sample. This commodity is made by cooking clams in water, adding salt, canning, and retorting. The product is used in institutions to make soups and broths. It is a sweet, slight greenish-yellow, mild clam-flavored liquid. Analysis of different commercial batches of juice showed that its composition varied. Average composition was 3.5% total solids, 2.0% salt, and 1.5% protein.

Because wash water at Station 3 was a dilute protein solution, it was necessary to concentrate the liquid two- to three-fold to bring its solids composition up to levels approximating those present in the marketed clam juice.

Different concentration techniques were used to increase the total solids content: (a) ultrafiltration, (b) open boiling, and (c) vacuum evaporation.

Materials were processed, canned, and retorted under different test conditions and evaluated for flavor characteristics after different storage times. Table 11 shows the composition of products concentrated by the different methods.

Tasting Session I

FLAVOR EVALUATION OF CLAM WASH WATER

Directions: You have before you 10 samples of processed clam wash water and a sample of canned clam juice "R".

Taste the reference sample "R" first and evaluate samples 1-10 against it. Samples 1-6 are unsalted so taste these first and then proceed to 7-10, the salted samples.

Flavor attribute	Intensity rating									
	Much less -5	-4	Mod. less -3	-2	Slightly less -1	Reference 0	Slightly more 1	Mod. more 2	4	Much more 5
Clam flavor										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
Fish flavor										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Figure 2. Taste Panel Work Form Comparing Selected Wash Water Flavors with a Commercial Clam Juice.

Tasting Session II

FLAVOR EVALUATION OF CLAM WASH WATER

Directions: As you taste the following 10 samples, please jot down a few descriptive words which characterize the flavor of these samples.

Please base your comments* on the sample with respect to "R".

Sample	Description
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

* Feel free to make comparisons such as, "#3 is more clammy than #4".

Figure 3. A Taste Panel Work Form to Describe a Flavor Profile of Clam Wash Water

TABLE 11. SELECTED CHARACTERISTICS OF CONCENTRATED SAMPLES OF WASH WATER FROM STATION 3

Sample type	Protein	Total solids	Protein as % of total solids
		%	
Clam juice	1.36	3.6	37.78
Juice from fresh clams	2.47	6.4	38.59
Ultrafiltration - p.m. shift			
No salt, retorted	2.31	3.1	74.19
No salt, unretorted	2.50	3.15	79.36
Ultrafiltration - a.m. shift			
No salt, retorted	0.49	0.7	70.00
No salt, unretorted	0.53	0.8	66.25
Salt, retorted	1.45	2.6	55.62
Salt, unretorted	1.57	2.8	56.14
Open boiling - a.m. shift			
No salt, retorted	1.35	3.1	43.55
No salt, unretorted	1.47	3.15	46.67
Salt, retorted	2.34	5.4	43.33
Salt, unretorted	2.25	5.0	45.00
Vacuum evaporation - a.m. shift			
No salt, retorted, 80°C	-	0.9	-
Salt, retorted, 80°C	-	3.4	-
No salt, retorted, 50°C	-	0.8	-
Salt, retorted, 50°C	-	3.0	-

The following process was developed to convert clam wash water into clam juice which is now marketed by the company:

(1) Wash water from mincing pumped directly into a steam-jacketed kettle.

(2) Boiled for 30-40 minutes to concentrate and remove objectionable volatiles.

(3) Concentrated juice strained to remove coagulated clam proteins.

(4) Salt added.

(5) Product canned and retorted.

The finished product is equivalent to conventional clam juice made by boiling clams in water in a kettle cooking-type operation.

Opportunities to Decrease Waste Volumes

Station 3 wash water contributed about half of the total organic load wasted to the sewer in this plant operation. The removal of nutrients from the waste flows would appreciably diminish waste treatment costs from this type of an operation.

Station 1, as indicated in Tables 1, 2, and 3, uses 80% of the total water and contributed about half of the total BOD load.

Water and waste flow continuously even though the clam meat which needs washing is batch produced by buckets of clams from a manual shucking operation.

Existing washing equipment can clean more than three times the amount of clams now being sent through the system. If the operator at Station 1 would operate the wash water only when clams traverse the tumbling spray system, it would be possible to cut water consumption about 60%. In addition, wash water spent in Station 2 could be used to pre-rinse clams at a dump table prior to wash Station 1. Fresh water is now used to prewash clams before the Station 1 washing equipment.

By combining water economies from Station 2 with intermittent flow rather than continual water use in Station 1, the total water used for both stations could be reduced from about 70 gpm to 30 gpm. The drop in water consumption for six operating hours would be 6 hours x 60 minutes/hr x 40 gpm, or 14,400 gallons per day. This is half the daily volume now utilized.

Station 3 would generate little to no waste but would increase clam juice volume by using the 5 gpm as product rather than waste as shown in Table 1.

WASTE TREATABILITY STUDY

Concurrent to the emphasis placed upon in-house methods to reduce waste, some of the group carried out a waste treatability study. The objectives of this phase of the project were as follows:

(1) Characterize the clam processing waste water as concentrated waste at Station 3 and as composite waste of the three stations mixed in the 12-2-1 ratio.

(2) Determine if these kinds of waste are amenable to simple aerobic biological treatment.

(3) Learn if usable food products would be captured from clam processing

waste water through physical-chemical treatments such as a coagulation-sedimentation system.

Project Approach

Waste samples were collected separately from the three stations in the processing line; the first two being the washing operation with the third a combination wash and mince operation. Samples were immediately frozen and transported to Cornell in 20 gallon pails and stored in a -30°F walk-in freezer. Composite mixtures were prepared by mixing appropriate amounts of waste in a 12-2-1 ratio. Station 3 was further treated separately with special flocculents to learn if organics therein might be economically separated into more concentrated fractions.

Coagulation-Sedimentation Tests

Jar tests were used to determine optimal coagulation doses in conjunction with appropriate turbidity measuring instruments.

Once optimal dosages were determined, the effluents were characterized by parameters such as: TKN, COD, and total solids. Along with coagulation-sedimentation tests, various combinations of centrifugation and filtration were employed. The coagulants used in a series of tests included: tri-valent solids, alum and ferric chloride, a synthetic polyelectrolyte (Dow A 23), a cellulose gum (Herculus Type 7HF), and a natural polymer chitosan. The results of these tests are presented in Tables 12, 13, and 14.

TABLE 12. SUMMARY OF OPTIMAL DOSAGES

Coagulant	Concentration	Turbidity reduction
	----mg/l-----	---------%---------
Composite waste		
$FeCl_3$	25	78
Alum	50	75
Chitosan	5	81
Dow A-23	1	62
Concentration waste (Station 3)		
$FeCl_3$	80	75
Alum	140	77
Chitosan	10	65
Dow A-23	7	66
Hercules cellulose gum	10	76

TABLE 13. COMPOSITE WASTE RESULTS

Test	Reduction			
	TS	TKN	COD	Turbidity
	%			
Centrifugation alone	8.8	13.3	0.0	58.3
Coagulation alone				
Alum	2.8	6.6	2.8	50.0
$FeCl_3$	2.8	6.6	2.8	76.6
Chitosan	2.8	14.6	15.7	80.0
Blank	1.3	0.0	0.0	33.3
Coagulation-Centrifugation				
Alum	9.8	14.6	2.8	63.3
$FeCl_3$	9.6	14.6	25.7	80.0
Chitosan	11.4	16.0	37.1	86.6
Blank	7.5	2.6	0.0	58.3

These tests indicate that clam processing waste does not appear to be especially amenable to coagulation-sedimentation treatment. What did come to light in determing the optimal coagulant dosages for the five coagulants used in the study was that substantial turbidity reduction occurred with little reduction in TKN, TS, or COD in dilute or concentrated wastes. We can only conclude from these data that opportunities for chemical-physical treatment do not appear promising.

Table 12, 13, and 14 show optimal dosage data from jar tests. Note the percentage reductions in turbidity with little improvement in organic composition. Chitosan, a shell waste product itself, exhibits interesting turbidity reduction characteristics.

TABLE 14. CONCENTRATED WASTE RESULTS

Test	Reduction TS	TKN	COD	Turbidity
	-----	-----	%	-----
Filtration alone	6.9	5.7	10.9	73.3
Centrifugation alone	7.8	1.7	17.7	53.3
Coagulation alone				
Alum	2.7	5.3	15.0	64.0
$FeCl_3$	3.6	3.3	9.6	46.0
Chitosan	3.9	5.7	16.4	88.6
Blank	0.6	0.3	1.3	13.3
Coagulation-Centrifugation				
Alum	8.3	7.1	19.1	75.3
$FeCl_3$	8.4	5.9	24.6	71.3
Chitosan	11.2	7.6	46.6	94.0
Blank	7.9	1.7	17.7	53.3

BIOLOGICAL TREATMENT

A bench scale study was carried out with liquid waste collected from the single site clam processing plant to look at its biotreatability characteristics. Four laboratory size aerobic lagoons were designed and operated at volume retention times of 2.5, 5, 10, and 15 days. These lagoons were operated on a draw and fill basis, daily, at a constant temperature of 20°C. The tanks were sized as follows: (a) 10 liters to simulate a 15-day lagoon, (b) the other three containers were 5 liters each. Aeration and mixing of the liquids were achieved by using an air supply through a diffusion stone.

The units were seeded with a mixed liquid obtained from a nearby sewage treatment plant. Feed for the units, clam processing wastes, was obtained from composite samples obtained at the factory side and frozen in one-week portion amounts for use during the testing period. No additional nutrients were added to the feed since analysis of clam processing wastes showed the material was not deficient in nitrogen or phosphorous. However, sodium carbonate was added daily at the rate of 250 mg/l food to maintain adequate buffering capacity.

The units were fed and wasted daily for a period of three solid retention times (SRT) before steady state data were taken. At steady state the pH values of all four units remained relatively constant and the following parameters were monitored for mixed liquors: total chemical oxygen demand (COD), total solids (TS), total volatile solids (TVS), suspended solids (SS), total Kjeldahl nitrogen (NH_3-N), ammonia as nitrogen (NH_3-N), nitrite (NO_2-N), nitrate (NO_3-N), pH, and temperature. The effluent analysis included SS, total COD, and biochemical oxygen demand (BOD).

In these kinds of treatment, the principal objectives of an aerobic biological process is the removal of colloidal and dissolved organic compounds by microbial metabolism. Bacterial cultures in a continuously mixed and aerated reactor utilize the soluble organic substrate for energy and growth. Theoretically the end products of this aerobic process are carbon dioxide, water, and microbial mass which is then removed by some kind of physical process. An equation is shown to illustrate this process:

$$C_NH_aO_b + N\,H_Y^+ + O_2 \;\underline{\text{bacteria}}\; C_5H_7O_2N + CO_2 + H_2O$$

Small amounts of solubilized phosphorous and nitrogen compounds are needed as nutrients to keep the growth steady. Table 15 shows pertinent waste characteristics of material used to feed the four systems.

TABLE 15. WASTE CHARACTERISTICS

Analysis	Concentrated waste (Station 3)	Composite waste* (Stations 1, 2, 3 mixed in 12:2:1 ratio)
	mg/l	
Total COD	3590	837
Soluble COD	3672	614
BOD	2452	463
TS	5380	2528
TVS	4420	1204
SS	97	161
VSS	90	138
TKN	282	113
NH_3-N	39.2	9.3
Alk	10 as $CaCO_3$	54.2 as $CaCO_3$
PO_4	150	40
TDS	2830	1695

* values are average of the nine food portions

Chemical oxygen demand (COD) removal efficiencies are listed in Table 16.

TABLE 16. COD REMOVAL EFFICIENCIES

Date	Solids retention time (SRT) 2.5 days	5 days	10 days	15 days
	%			
8/1		94.5	96.4	98.9
8/4		94.5	97.8	98.9
8/6		95.8	97.9	98.9
8/7		95.8	96.9	98.9
8/13	96.6			
8/14		91.9	91.2	95.1
8/15	89.7	93.4	91.2	94.9
8/18	91.3			
8/20		93.2	89.9	94.0
8/21	94.4			
Average	93.0	94.1	94.4	97.0

Table 17 through Table 20 summarize the mixed liquor and effluent characteristics of the reactors in the 2.5-, 5-, 10-, and 15-day experiments.

It was found that greater than 90% COD reductions were achieved at a hydraulic retention time of 2.5 days or more, and total nitrification occurred in a retention period of five days.

The results of the study indicate that clam processing waste appears to be readily amenable to aerobic biological treatment. Like operations might consider variations of this kind of treatment attractive for on-site pretreatment action where necessary.

TABLE 17. 5 DAYS RETENTION WITH AEROBIC TREATMENT - AUGUST 1975

Date	Mixed liquor									Effluent		
	TS	SS	COD	TKN	NH_3-N	NO_2-N	NO_3-N	pH	VSS	SS	COD	BOD
	mg/1									mg/1		
8/1	1920	712	538	62	0	0	72	6.7	612	28	40	14
8/4	2155	480	456	55	0	0	65	6.7	412	28	40	7
8/6	2455	376	440	53	0	0	54	6.1	312	26	32	26
8/7	2270	470	432	50	0	0	61	6.9	412	26	32	19
8/14	2235	480	534	40	0	0	63	6.8	420	69	75	30
8/15		479	518					6.8	413	40	61	
8/20	2210	618	543					6.5	482	37	82	10

TABLE 18. 10 DAYS RETENTION WITH AEROBIC TREATMENT - AUGUST 1975

	Mixed liquor									Effluent		
Date	TS	SS	COD	TKN	NH_3-N	NO_2-N	NO_3-N	pH	VSS	SS	COD	BOD
	mg/1									mg/1		
8/1	2015	618	489	45	0	0	83	7.0	50[illegible]	32	24	10
8/4	2085	434	408	50	0	0	85	7.0	346	30	16	
8/6	2365	416	416	50	0	0	58	6.0	370	32	16	25
8/7	2525	320	350	38	0	0		6.9	252	48	24	19
8/14	2306		494	43	0	0	70	6.7		56	82	26
8/15		422	445					6.5	346	57	82	
8/20	2080	446	461					6.5	384	82	124	30

TABLE 19. 15 DAYS RETENTION WITH AEROBIC TREATMENT - AUGUST 1975

Date	Mixed liquor									Effluent		
	TS	SS	COD	TKN	NH_3-N	NO_2-N	NO_3-N	pH	VSS	SS	COD	BOD
	mg/1									mg/1		
8/1	1975	382	408	49	0	0	80	6.9	332	8	8	5
8/4	2015	422	399	49	0	0	88	6.9	346	24	8	
8/6	2570	398	432	54	0	0	83	6.0	334	8	8	16
8/7	2140	358	367	45	0	0		6.7	308	10	8	11
8/14	2165	440	432	42	0	0	83		370	34	45	20
8/15		386	424					6.5	336	18	47	
8/20	2105	482	465						396	40	73	20

TABLE 20. 2.5 DAYS RETENTION WITH AEROBIC TREATMENT - AUGUST 1975

	Mixed liquor									Effluent		
Date	TS	SS	COD	TKN	NH_3-N	NO_2-N	NO_3-N	pH	VSS	SS	COD	BOD
	mg/1									mg/1		
8/13	1952	515	216	66	5.6	32	20		476	96	61	
8/14	1995	524	588	57	0	37	18		424	46		39
8/15		492	600					7.2	398	28	96	
8/18	2207	470	530	56	5.6	31	14	7.1	408	64	81	38
8/21	2540	848	750	71	7.7	37	11	7.0	523	70	68	62

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PILOT PLANT PRODUCTION OF A FUNCTIONAL PROTEIN FROM FISH WASTE BY ENZYMATIC DIGESTION*

G. O. Bucove** and G. M. Pigott**

INTRODUCTION

For several years, researchers of the Institute for Food Science and Technology at the University of Washington have been investigating methods of utilizing both marine food processing waste and fish stocks not normally used for human consumption. The primary goal of this research has been to produce, from waste and underutilized species, a product of higher nutritional and economic value than ordinary fish meal, while minimizing pollution. The goal has not been to solve an existing pollution problem, but to upgrade an existing use of raw material without creating a problem.

Of the approximately 70 million metric tons of fish caught annually worldwide, between 30 and 40% is used directly for animal feed.(1) Much of this fish is from species too small, too boney, or too oily for direct human use, and is reduced to fish meal. Fish meal is a good animal food supplement, but loses nutritional value during direct flame drying and has serious odor and liquid waste problems.

Of the remainder of the world catch, which is processed in one way or another for human food, up to 65% becomes a by-product or waste. A salmon fillet line, for example, uses only about 35% of the whole fish. Canning lines are more efficient, utilizing up to 65% of the whole fish.(2) At present, much of this waste becomes serious local pollution or, at best, is reduced to a low grade animal feed. This does not have to be the case, since the non-edible or waste portion (viscera, head, filleted frame, etc.) is very similar in terms of proximate analysis to the edible portion, as seen in Table 1.

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**Respectively Graduate Research Assistant and Professor, Institute for Food Science and Technology, College of Fisheries, University of Washington, Seattle, Washington 98195.

TABLE 1. PROXIMATE COMPOSITION OF A TYPICAL TRAWL-CAUGHT FISH(3)

Constituent	Whole Fish	Edible Portion	Non-edible portion
Water	89.9%	83.6%	81.2%
Lipid	3.5%	0.8%	4.4%
Protein	12.7%	15.2%	11.7%
Ash	2.7%	1.1%	3.5%

Over the last ten to twenty years, there have been numerous proposed methods to utilize fish processing wastes and underutilized species to produce a high grade animal or human food product - usually called Fish Protein Concentrate or F.P.C. Few have been successful. The problem is great: to produce an inexpensive, low lipid, highly nutritious product, free of fish odor and taste, with long-term storage stability not requiring refrigeration or extensive packaging. Most of the conventional fish protein concentrate methods use an organic solvent extraction to remove lipid. These methods entail complex, expensive engineering and have difficult problems with solvent recovery and solvent-contaminated product and waste streams. The F.P.C. from solvent extraction is furthermore a non-functional protein. It cannot be rehydrated with water and therefore has a limited potential as a food additive.(4) Many of the other methods have never successfully left the bench laboratory stage due to economic and engineering scale-up problems.(5)

This paper presents our ongoing research on a biological F.P.C. method developed to produce a functional, soluble, high-quality protein product, which could have immediate marketability as a milk solids substitute in animal feed formulations and a good potential as a human food additive.(6) We expect to present a complete engineering report on the process this August at the First International Congress on Engineering and Food at Boston, Massachusetts.

PILOT PLANT PROCESS

Figure 1 presents a flow chart of the enzyme digest F.P.C. process. A brief overview here will be followed by detailed descriptions of the various steps. First, the raw material is mechanically deboned. The skin and bones can be dumped overboard if processed at sea, or reduced to meal or fertilizer ashore. The fish flesh is homogenized with water and placed into the enzyme reactor.

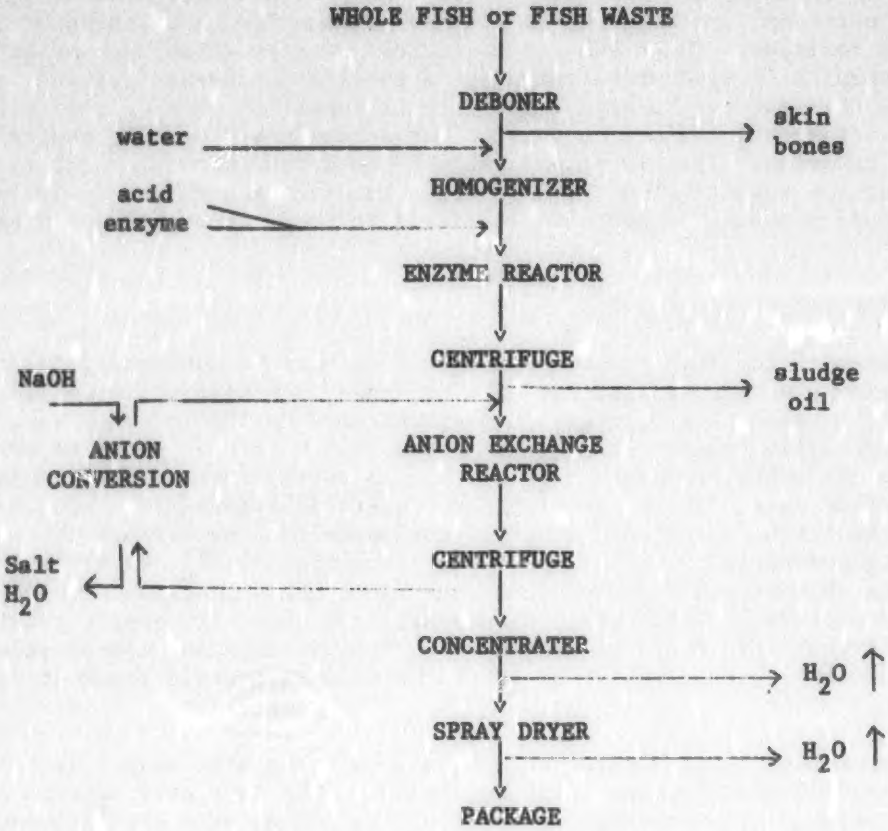
WHOLE FISH or FISH WASTE
DEBONER
water
skin
bones
HOMOGENIZER
acid
enzyme
ENZYME REACTOR
CENTRIFUGE
NaOH
sludge
oil
ANION EXCHANGE REACTOR
ANION CONVERSION
Salt
H_2O
CENTRIFUGE
CONCENTRATER
H_2O ↑
SPRAY DRYER
H_2O ↑
PACKAGE

Figure 1. Flow Chart - Enzyme Digest Fish Protein Concentrate.

Pepsin is the enzyme chosen for this process, since it allows good yields of soluble protein and has a low pH optimum (pH 2), resulting in minimal bacteriological problems during processing.(7,8) The enzyme breaks up the natural long-chain, high molecular weight fish proteins into smaller polypeptides, peptides, and amino acids with an average length of three or four amino acid residues. These shorter molecules are very soluble in water and can be mechanically separated from most of the lipid present, and the insoluble sludge fraction can be separated by centrifugation. The soluble protein fraction, after centrifugation, is still at a low pH and must be neutralized before being dried. This is accomplished in an anion exchange reactor, where the H^+ ions are removed from the solution. The ion exchange resin is regenerated and recycled. The neutralized liquid is then concentrated and spray dried.

RAW MATERIAL

The raw material for this process can come from various sources, mainly process wastes, as from fillet and canning lines, and underutilized industrial (or trash) fish. The original development work on this process used English sole fillet waste.(9,10) The process has also been shown to work well on salmon waste, assorted trash fish, and shrimp from "dirty" shrimp trawls, and on hake. If the in-plant type waste is treated in a sanitary fashion, the flesh can be used directly for human food by various processes of deboning and patty or artificial cutlet formation.(2,11) However, even poorly treated scraps off the process room floor make acceptable input for the enzyme process. Yields will be somewhat lower for very poorly treated fish, since the lipid tends to become more tightly bound in lipo-protein complexes, and emulsions result which lower the soluble protein fraction during centrifugation.(12)

The data presented in this paper were developed using hake caught in bottom trawls or as incidental catch in shrimp hauls. Hake is a good example of a plentiful pelagic species which is difficult to market as a direct human food fish. It has encountered fresh market resistance due to its texture, is expensive to fillet, has too much water in the flesh to make good frozen blocks, doesn't bind water well enough to make good minced products, and has a limited frozen storage life, due to active enzyme systems in the flesh. (13,14)

DEBONER

In this process, the first step could be done on shipboard. Bones and skin could be dumped at sea, and the deboned flesh held in tanks below deck, kept acidified at pH 3 to 4 for stability. When the vessel is in port offloading the primary product, a quick disconnect hose could be used to pump the slurried fish ashore for further processing. In this fashion, incidental catches such as the up to six pounds of fish caught for each pound of shrimp could be easily handled. Presently a great amount of extra equipment and manpower is required to utilize such fish and, as a result, millions of pounds are dumped overboard annually. Figure 2 shows a Japanese type deboner in use on a Pacific Northwest shrimp trawler preparing samples from a trashy shrimp haul. The bone and skin separation is quite good, the unused portion being quite dry and low in flesh. Recovery can be up to 80% with whole fresh fish, less with small fish, and as low as 50% from process waste, depending on the amount of flesh left on the frame.

The original work on this process did not include a deboning step before the enzyme reactor. The resulting slurry in the reactor required nearly constant addition of acid to retain a pH of 2, due to calcium and phosphate buffering activity. Deboning solved this problem, greatly reduced the precipitation of protein during neutralization, increased the protein yield, and also decreased the ash content of the final product.

ENZYME REACTOR

The remaining process steps were carried out in the Food Processing Engineering laboratory at the University. Figure 3 shows the pilot plant developed in the engineering lab for this process. First the fish is homogenized with water. The homogenization thoroughly integrates the fish and water and allows a faster initial reaction rate. Too much homogenization, however, has been shown to increase emulsification of lipids and proteins, slowing the enzyme activity and lowering yields.

Following the homogenizer, the fish slurry drops into the enzyme reactor shown in Figure 4. The reactor was designed with a conical bottom, so that the slurry can be mixed in two fashions: by pumping out the bottom and recirculating, and by mixing with a paddle. At the beginning of a run, when HCl is added, the slurry thickens to a paste-like consistency and the paddle alone is insufficient. Thorough mixing is needed to distribute the enzyme throughout the slurry. After the reaction proceeds one-half to one hour, the mixture becomes very soupy, and the paddle works well for continued agitation.

The amount of water added can make a difference in viscosity and ease the mixing, but each pound added must be removed later. Successive runs show small increases in protein yield with greater amounts of water. The optimum chosen in this process is a 2:1 ratio, with 2 parts by weight of deboned fish to 1 part water. The original work used a reaction temperature of 37°C, the temperature thought to be optimum. Work on the pilot plant has shown, however, that by using higher temperatures of 45-50°C the protein recovery is faster and nearly the same yields can be accomplished with half the amount of pepsin originally prescribed.

Figure 5 shows typical recovery curves for the reaction at 48°C. The percent of the original protein that is recovered in the soluble fraction after centrifugation is plotted against time. Yields are affected by the amount of water added, amount of pepsin, mixing regime, temperature, quality of fish, and separational force in centrifugation. The top line represents nearly optimal conditions, giving a 73% recovery of protein; the second curve, with half the amount of costly enzyme, gives only a few percent lesser yield and

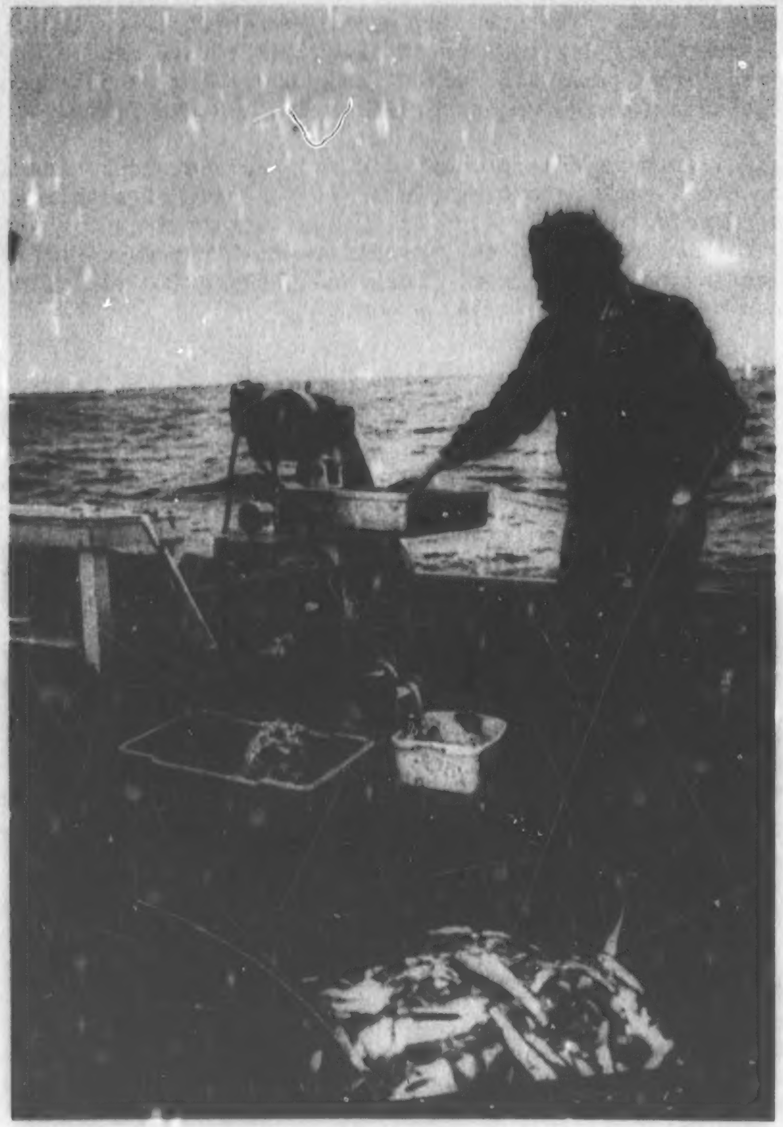

Figure 2. Deboner in Use.

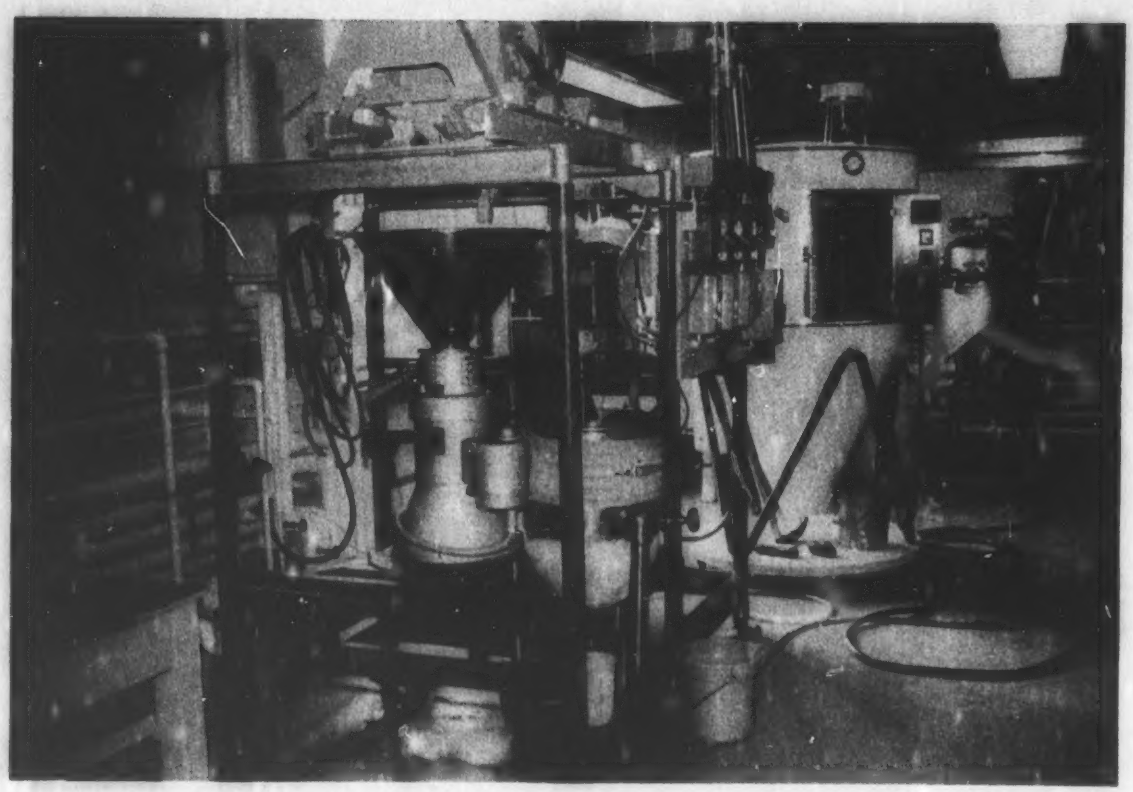

Figure 3. Pilot Plant

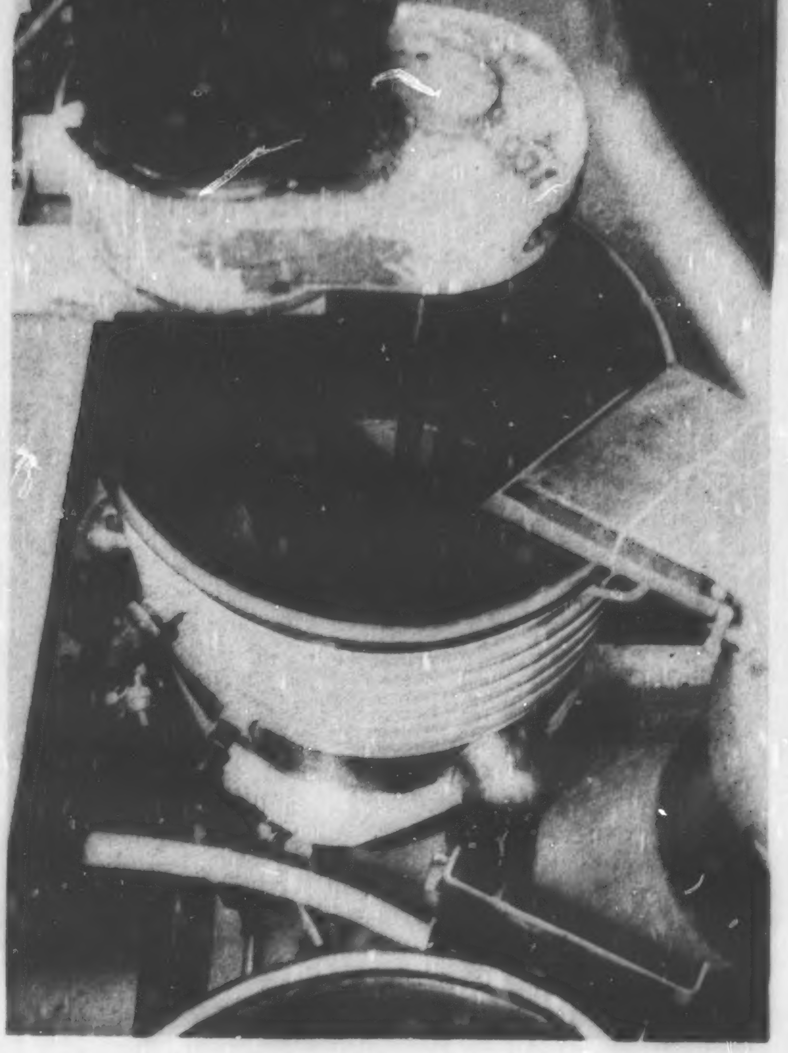

Figure 4. Enzyme Reactor

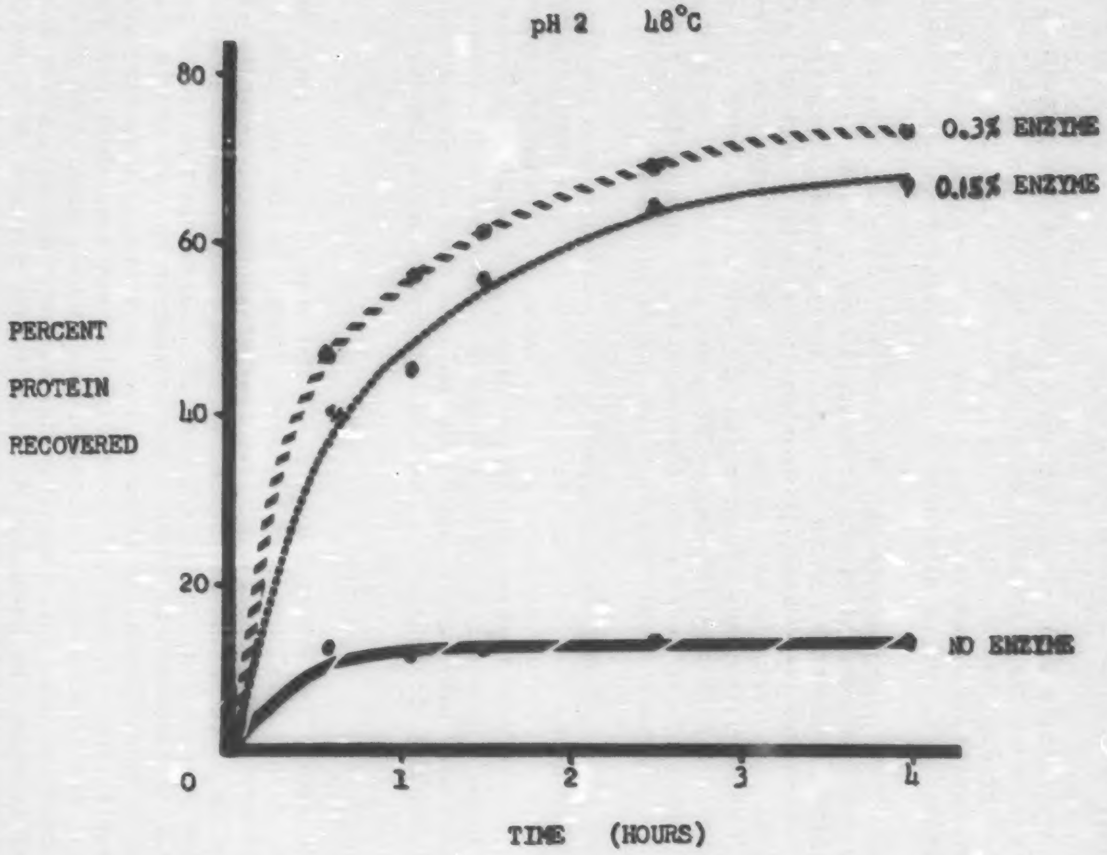

Figure 5. Percent Protein Recovered in the Liquid Fraction.

is clearly more economical.

The line at the bottom of Figure 5 shows the yield with no enzyme added and is shown for reference. In the production of fermented fish sauces and other types of autolysates (without added enzymes), the pH is not lowered to 2, and protein yields approach 30 to 45%, but only after 48 or more hours.(8,15)

ANION EXCHANGE

During the preliminary work on this process, the low pH liquid leaving the centrifuge was neutralized by addition of base, in this case NaOH. The resulting final product had a very high salt level of 25-30% (89% of which was NaCl). High salt is a drawback to any product to be used as a milk substitute in feed formulations, and an alternative neutralizing process was needed.(16)

Several ion exchange resins were investigated and continue to be investigated to overcome the high content of the original product. Dowex 2-X8, a commercial grade strong base anion exchange resin, has given good results. This resin will neutralize the soluble protein fraction to pH 7 with 1/3 vol./vol. wet bed resin. The resin is reconverted to the OH^- form with two volumes of 1 N NaOH. Both these volumes of resin and NaOH could be reduced in a commercial operation, if 2-X8 were chosen, because the protein need only be neutralized to a pH near 5, and because the reconversion is an equilibrium reaction and approaches adequate completion with one volume of NaOH.

With a strong base exchange resin, a tank reactor appears to allow the best control. Resin beads are added to the tank as the protein liquid is added and adjusted to the proper effluent pH. The resin could then be separated in a specially designed basket centrifuge which would retain the beads in the basket for subsequent washing and reconversion. Also under investigation are different weak base exchange resins which could be handled entirely in columns, minimizing the possible mechanical breakdown of the beads.

DRYING

After neutralizing, the material is dried. The method of drying can have a large effect on the final product.(17) Spray drying is the best choice for this type of product, since it minimizes loss of nutrients, enhances rehydratability, and tends to whiten the product. Spray drying, however, is not economic with an incoming liquid less than 30% solids, so the liquid protein fraction must be concentrated first. The concentration step should also minimize nutritional losses, so either a low temperature, long time process (as in vacuum drying) or some efficient high temperature, short time process is required. The trouble with a proteinaceous liquid, such as in this case, is that it tends to bake onto heat transfer surfaces quickly, which lowers the dryer efficiency. We have used a vacuum rotary dryer at 40°C and 25 in. Hg vacuum with good results, and are currently developing a submerged combustion concentrating unit. This unit burns propane in a specially designed chamber under the surface of the liquid, releasing hot gas bubbles which rise through the liquid, acting as very efficient heat transfer surfaces.

PRODUCT

The product leaving the spray dryer is a white, fluffy powder. It has the characteristic bitter taste of small polypeptides and amino acids, but this bitter taste is considerably less with the ion-exchanging and with shorter enzyme reaction times than it was in the original process. The bitterness should not be objectionable in animal feed formulations at the 5 or 10% level. We also hope to present in August further information on the product's potential use as a human food additive. A class this term in the School of Home Economics at the University is trying the material in different food formulations at varying levels and will produce taste panel data.

A proximate analysis of the product is presented in Table 2. It compares well to fish meal at 30 to 50% protein, milk solids at ~35% protein, and many of the organic solvent extracted FPC products at ~70% protein.

TABLE 2. PROXIMATE ANALYSIS - ENZYME DIGESTED HAKE FPC

Total Amino Acids	84.6%
Kjeldahl Protein	85.0%
Moisture	8.2%
Ash	8.9%
Lipid	0.8%
Lead	<0.01 ppm
Mercury	<0.5 ppm
Fluorides	Neg. (AOAC)

Table 3 presents an amino acid analysis of the product compared to casein for reference. The FPC has a very good essential amino acid profile. Lysine is quite high; the aromatic amino acids are lower and limiting. Tryptophane was lost to a great extent in the original work and is generally considered limiting in acid hydrolyzed fish protein. By removing the bones and ions such as Ca and PO_4 which help to complex and precipitate tryptophane, the recovery is much improved.

TABLE 3. AMINO ACID ANALYSIS - ENZYME DIGESTED HAKE FPC

	FPC	ANRC Reference Casein
Isoleucine	3.9	5.0
Leucine	7.3	7.5
Lysine	8.5	6.7
Phenylalanine	3.3	4.0
Tyrosine	2.7	5.2
Cystine	1.0	0.3
Methionine	2.8	2.3
Threonine	3.8	4.0
Tryptophane	1.1	1.0
Valine	4.5	5.9
Total Amino Acids	84.7	89.8

Table 4 gives the results of a Protein Efficiency Ratio (PER) assay performed with the hake FPC.

TABLE 4. PROTEIN EFFICIENCY RATIO

PER	FPC-Enzyme Digest	FPC-Enzyme Digest plus Tryptophane	Casein Control
Weight gain/Protein consumed	3.44	3.45	3.00
Percent of Casein Control	1.15	1.15	1.00

To confirm the retention of tryptophane, 1% (of the total amino acids) of tryptophane was added to one diet with no significant change from the unchanged FPC. The PER results indicate that this FPC product has a good quality dietary protein.

ECONOMIC SUMMARY AND CONCLUSION

Listed in Figure 6 are numbers for both an underutilized species (hake) and fish waste (cod fillet trimmings). Hake gets up to 80% recovery deboned, less if small or if a lot of shrimp waste is included. The fillet waste gives a yield of about 50%. Hake is also slightly higher in protein, 13% compared to 11 1/2% for the fillet waste. Hake is currently being landed north of Seattle for between one and two cents per pound. One cent per pound is a convenient figure for scrap, as it can vary from a few cents to a negative cent or two to haul it away.

Pepsin is the larges process expense at the current price of $28 per pound, but we have confidence this cost can be substantially reduced. The raw material being used is hog stomach mucosa at about 50 cents per pound, giving about 4% yield of 1:10,000 N.F. pepsin, for a raw product cost of about $12.50 per pound pepsin. We have ongoing research involving pepsin preparations and, again, hope to have more information later.

The sludge is about 9% protein, has a good amino acid array, and is proposed as an animal feed, especially in formulations such as aquaculture fish feed, where insolubility is a positive factor. Inside the box in Figure 6, 2,700 gallons of liquid at about 7.5% protein goes to the anion exchange. Nine hundred gallons of mixed bed resin will bring the pH to 7, and require 1,800 gallons of 1 N NaOH for reconversion. It is anticipated, as mentioned earlier, that both these quantities can be reduced. On the basis presented here, the per final product pound costs for pepsin are $0.35; for raw material, $0.23; and estimating $0.20-0.25 for processing, we feel this product could be put out the door at a cost on the order of $0.80 per pound. This compares well with non-fat milk solids selling now at about $0.60 per pound at 35% protein, and with casein selling at $1.65 per pound.

In conclusion, this is a process capable of producing an excellent product with very few effluent or waste stream problems, promising marketability and economics, and relatively simple engineering. This may well be a process that will be able to leave the laboratory and make its way in the real world.

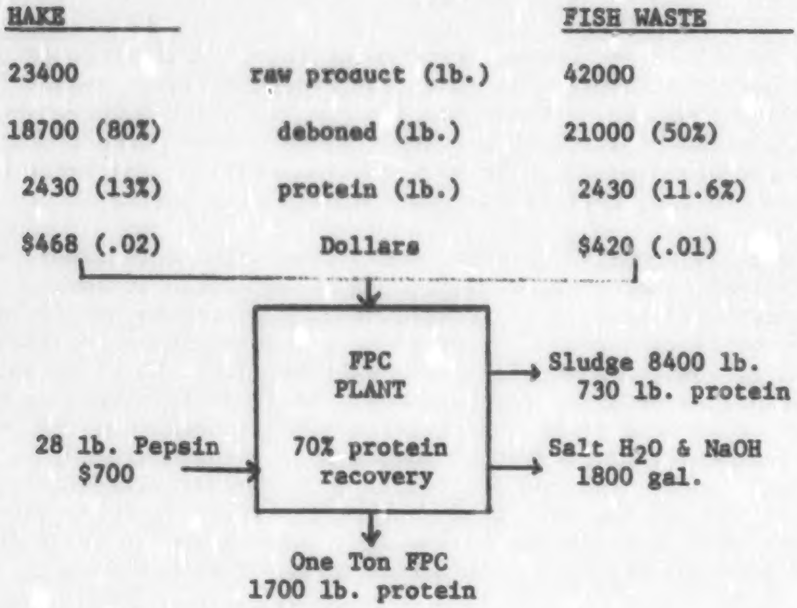
HAKE
FISH WASTE
23400
raw product (lb.)
42000
18700 (80%)
deboned (lb.)
21000 (50%)
2430 (13%)
protein (lb.)
2430 (11.6%)
$468 (.02)
Dollars
$420 (.01)
FPC PLANT
70% protein recovery
28 lb. Pepsin $700
Sludge 8400 lb. 730 lb. protein
Salt H2O & NaOH 1800 gal.
One Ton FPC 1700 lb. protein

Figure 6. Protein Balance - One Ton Final Product (85% Protein).

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AN IMMOBILIZED-ENZYME PILOT PLANT FOR THE TREATMENT OF ACID WHEY**

by

Dr. M. Charles*, Dr. R. W. Coughlin* and Dipl.-Ing. K. Julkowski

INTRODUCTION

We have previously developed an economical bench-scale process for hydrolyzing the lactose in acid whey based on the use of a simple-to-prepare inexpensive immobilized-lactase catalyst incorporated in a fluidized-bed reactor(1). This process has now been scaled-up and has been incorporated in a pilot plant having a maximum daily capacity of 400 gallons of whey. The pilot plant also has ultrafiltration and ion-exchange demineralization units and is constructed in such a fashion that any sequence of the three unit operations can be synthesized. Thus, the plant may be used to obtain data for scale up and economic evaluation of a variety of whey treatment strategies and at the same time to provide to potential users adequate supplies of various products (e.g., hydrolyzed raw whey, hydrolyzed whey permeate) for their own testing programs.

BENCH-SCALE WORK

Overview

A fluidized-bed hydrolysis reactor (1 inch diameter) employing a catalyst comprising lactase immobilized on small alumina particles was operated successfully at the Lehigh Valley Dairy (Allentown, PA) to hydrolyze the lactose in raw (unfiltered) cottage cheese whey. This work, which will be reviewed briefly, demonstrated the technical feasibility of the process, the superiority of fluidized-bed reactors, and the suitability of the catalyst, and provided data which indicated a favorable economic prognosis and which was used in the design of the pilot plant.

The Catalyst

The catalyst used in all bench scale experiments and in all pilot plant work to date was prepared as follows(2):

(1) Lactase was adsorbed from solution onto 150μ diameter alumina particles having a mean pore diameter of 4000 Å

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*Department of Chemical Engineering, Lehigh University, Whitaker Laboratory, Bethlehem, PA 18015

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and a surface area of approximately 4 cm^2/gm. These particles are available commercially (Carborundum SAEHA-32) and are presently employed in industrial catalytic reactors.

(2) The adsorbed enzyme was then crosslinked with glutaraldehyde and washed with citrate-phosphate buffer.

This simple inexpensive preparation which used only FDA-approved materials and which can be performed at room temperature with very simple equipment provides a catalyst having the following attributes:

(1) Excellent activity and long-term stability under actual operating conditions.

(2) Good fluidization characteristics.

(3) Freedom from microbial attack.

(4) Good mechanical integrity; less than 1/2% catalyst loss by attrition and elutriation for two weeks of on stream operation.

(5) A pH profile(2) (Figure 1) which is relatively flat over the normal pH range of acid whey.

(6) Temperature-reactivity characteristics(2) (Figure 2) permitting stable active behavior at temperatures between 55°C and 60°C which are close to the temperature of whey leaving the cheese vats and which tend to discourage microbial growth in the reactor.

More complete information concerning catalyst preparation and characteristics is available in previous publications(2,3,4).

The Fluidized-Bed Reactor

The rate of enzymatic hydrolysis of lactose is dependent on both lactose and galactose (reaction product) concentrations and hence a plug-flow continuous reactor will provide greater productivity than will other reactors(5). In theory, both fixed and fluidized-beds can be operated as plug-flow reactors and will give the same conversion of substrate for a given quantity of catalyst and reactor residence time assuming equal mass transfer resistances for both reactors which is essentially true for the present case. Therefore, the choice between the two will be dictated by mechanical considerations. In order to minimize reactor size and to increase productivity it is necessary to use a catalyst particle having a large active surface area per unit volume. In the case of immobilized-enzyme catalysts this dictates the use of the smallest practical particle (50μ-200μ). When such small particles are employed in fixed-bed reactors, two major difficulties are

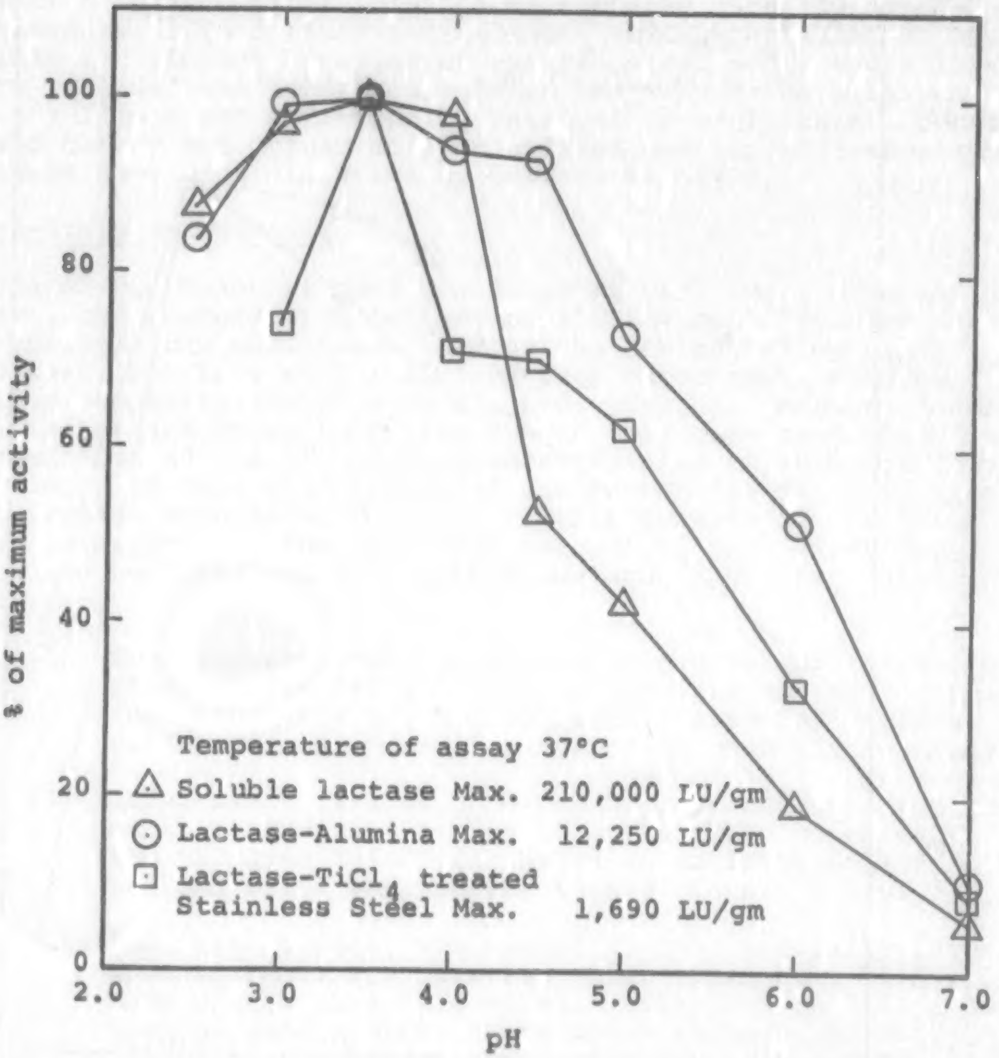

Figure 1. pH Profile.

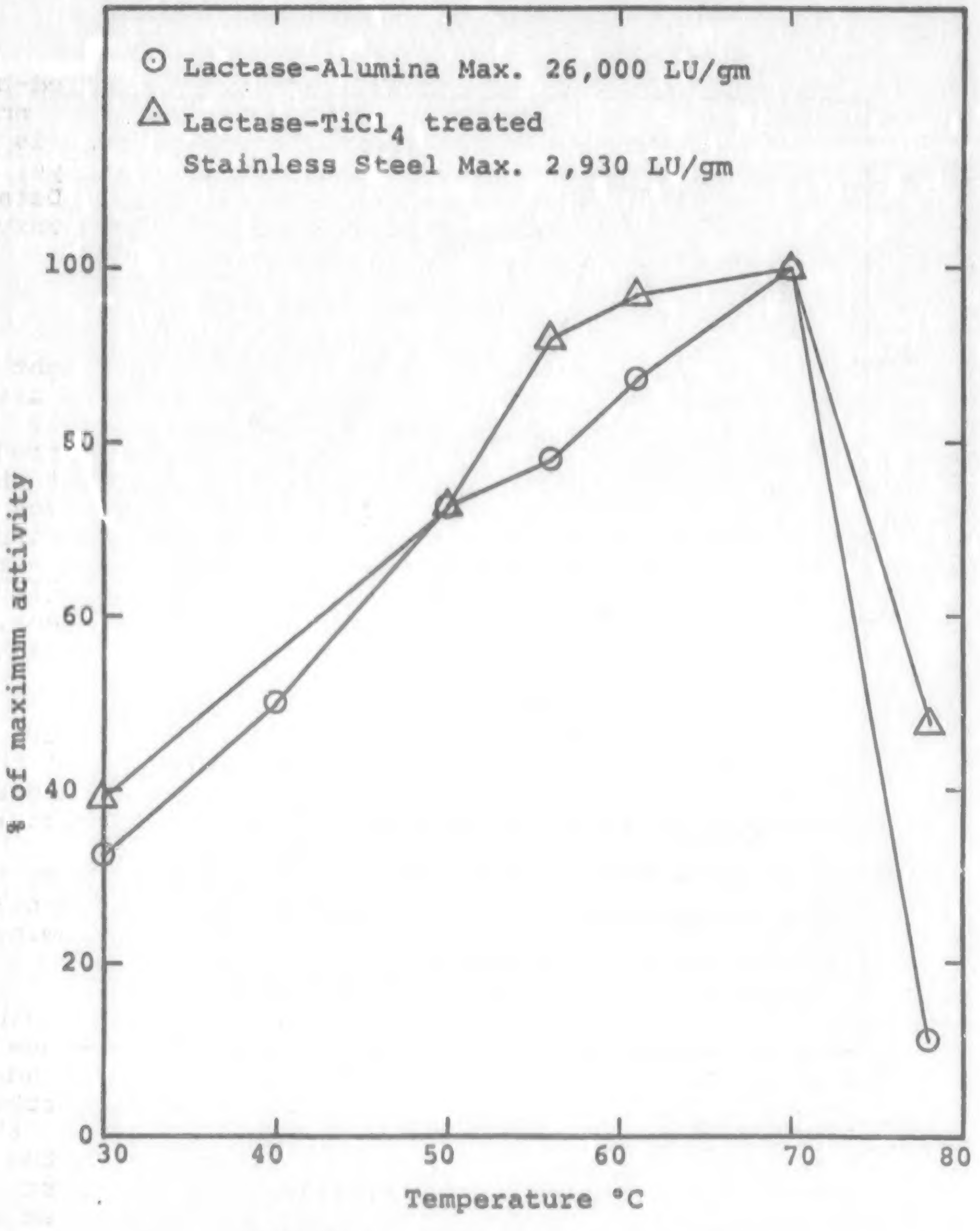

Figure 2. Temperature Profiles.

invariably encountered:

(1) Plugging results from particulates in the process stream and/or microbial growth on the catalyst in the column.

(2) High pressure drops.

Neither of these difficulties is encountered with fluidized-beds. Furthermore, liquid fluidized-beds are quite stable and do not exhibit the violent behavior of gas-fluidized beds; there is a sharp well defined interface between the top of the catalyst bed and the liquid and attrition of catalyst is negligible. Details of the theory and operation of fluidized-bed immobilized-enzyme reactors have been discussed by Charles et al(3).

Bench-Scale Experiments

Fluidized-bed reactors having a diameter of 1 inch, a height of 3 feet, and charged with lactase-on-alumina catalyst were used to hydrolyze raw unfiltered whey at the Lehigh Valley Dairy (Allentown, PA) in a number of long-term experiments conducted at various temperatures, flow rates, etc. Typical results of these experiments are given in Figure 3. In this case two columns each charged with 40 gms of catalyst were operated at 60°C continuously for almost 28 days with scheduled shut-downs for daily in situ sanitization with Iosan solution. Other details of operation are given in Figure 3. The important results of this experiment, which are analyzed and discussed elsewhere in greater detail(1,2), were:

(1) The reactors functioned without mechanical failure or plugging despite the high particulate content of the feed (the whey was not filtered); even large cheese curd particles passed unimpeded through the reactors.

(2) After an initial rapid decay in apparent activity the catalyst remained stable throughout the experiment; the catalyst half-life (based on activity following the initial drop) was greater than 60 days.

(3) The initial decay was caused by only partially reversible adsorption of whey protein which apparently blinds only some of the catalytic sites. After the initial adsorption of whey protein there appeared to be no further significant substrate-related decay. Therefore, the problem can be easily overcome by designing on the basis of reactor residence time based on catalyst activity following the rapid decay. (The problem will be greatly diminished when whey permeate is processed.)

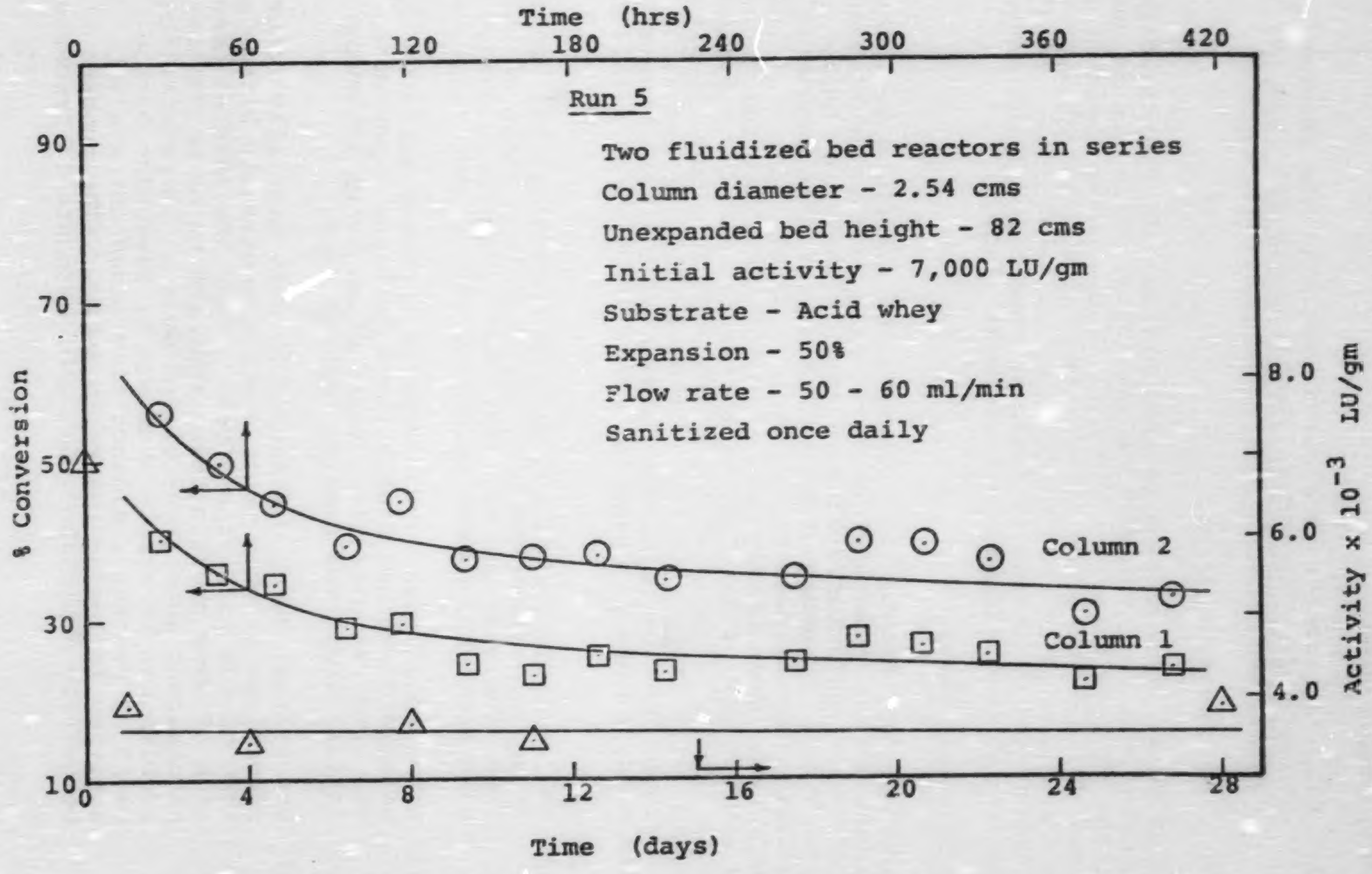

Figure 3. Long Term Dairy Experiment.

(4) Catalytic activity is not affected significantly by daily sanitization with Iosan.

PILOT PLANT

General Description

The results of the Dairy experiments were used in the design of pilot plant reactors having a maximum daily throughput of 400 gallons of whey. While the primary purpose of our work is to evaluate the reactors and catalyst at the pilot scale, it is clear that enzymic hydrolysis probably will be used in concert with ultrafiltration and/or ion exchange (or some other demineralization process) to produce commercially acceptable products but it is not clear which sequence(s) of the three operations will yield such products. Therefore we have included ultrafiltration and ion exchange units and have designed the system to facilitate synthesis of any sequence. Thus the system, which is illustrated in Figure 4, permits us to:

(1) provide various products to potential users for use in their own testing programs

(2) obtain data for scale up and economic evaluation of the various processing alternatives.

It should be noted that in addition to enhancing product acceptability the use of ultrafiltration and/or demineralization might lead to longer immobilized-enzyme catalyst half-life(2,6,7). This warrants investigation at the pilot scale because a significant increase in catalyst half-life will markedly decrease the cost of hydrolysis(2).

Operating and Design Details

Raw whey may be hydrolyzed directly or pretreated by ultrafiltration and/or ion exchange and subsequently hydrolyzed. In the first case, which is easily accomplished when fluidized-bed hydrolysis reactors are used but quite difficult with fixed-bed reactors, raw whey is heated to the desired hydrolysis temperature (50-60°C) by passing it through a stainless steel shell and tube heat exchanger (American Standard S3CF-03014) from which it flows to the immobilized-lactase fluidized-bed hydrolyzers where the whey lactose is converted to glucose and galactose. The pilot plant has two hydrolyzers each being 3 inches in diameter by 6 feet high and containing approximately 4 kilograms of catalyst. Good liquid flow distribution is provided by a conical inlet section at the base of each column. Support screens which are known to clog quickly, particularly when raw whey is processed, are not used; flow to the column is started and stopped by a quick-acting ball valve which prevents catalyst drainage.

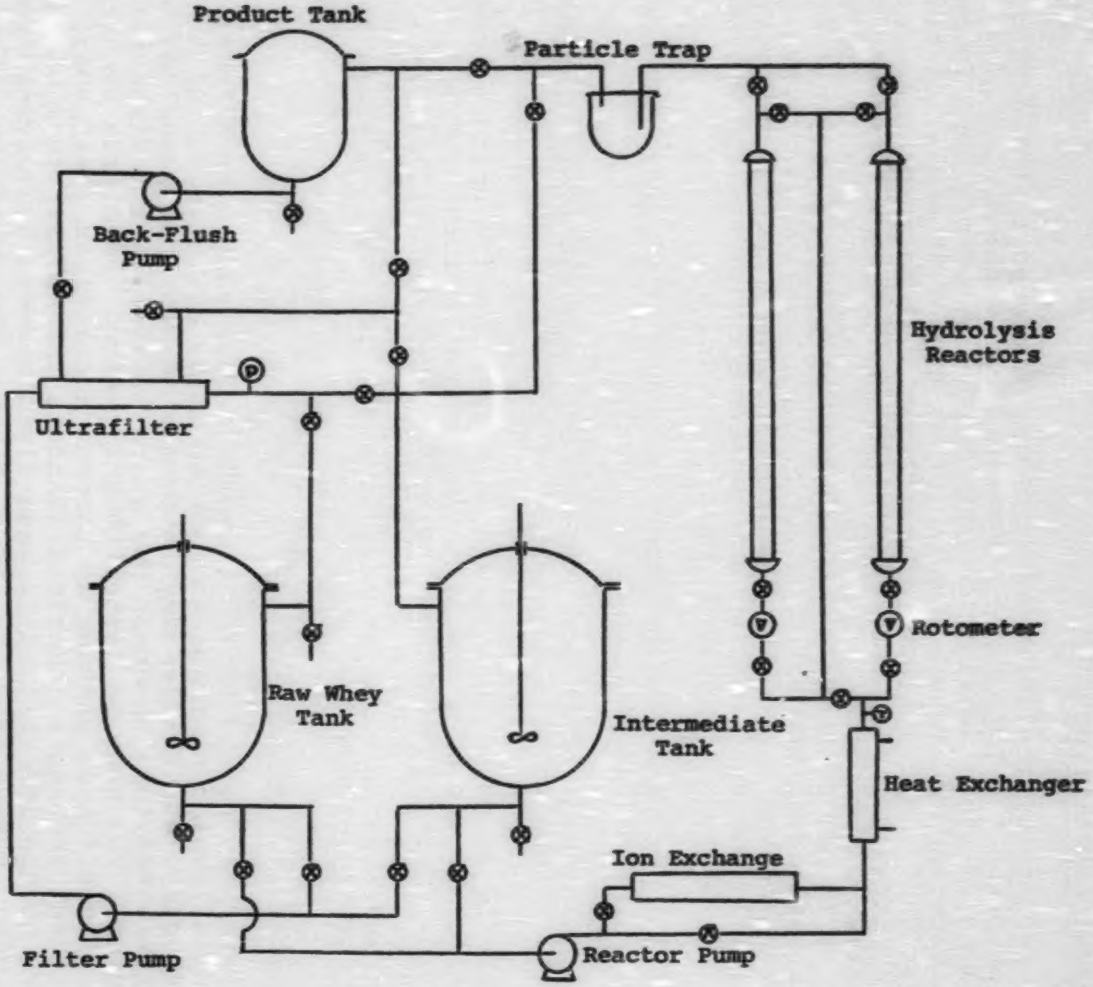
Product Tank
Particle Trap
Back-Flush Pump
Hydrolysis Reactors
Ultrafilter
Rotometer
Raw Whey Tank
Intermediate Tank
Heat Exchanger
Ion Exchange
Filter Pump
Reactor Pump

Figure 4. Pilot Plant Flow Diagram.

Hydrolyzed whey then flows through a particle trap to remove any catalyst which might elutriate and subsequently to the ultrafiltration and/or ion exchange units if post-hydrolysis treatment is desired. It should be noted that very little of the catalyst is elutriated; a liquid fluidized bed is characterized by very gentle agitation of the catalyst particles and a very sharp liquid-catalyst interface at the top of the bed. In controlled experiments(8) less than 1/2% of the catalyst in a 1 inch diameter reactor (which is not as well-behaved as the 3 inch diameter pilot plant reactors) was elutriated during two weeks of continuous operation.

If prehydrolysis treatment is desired, raw whey can be ultrafiltered and/or demineralized. Ultrafiltration is achieved by a Romicon (H15-45-XM50) filter which is of the type(9) already proven for separation of protein from acid whey. It has a molecular weight cutoff of 50,000 and an average flux of 15 gsfd and permits recovery of valuable whey protein. Ion-exchange is used for demineralization. The pilot plant demineralizer consists of an anion exchange column containing 0.26 cubic feet of Duolite ES-340 resin and a cation column containing 0.26 cubic feet of Duolite C-20 resin. The columns are both 4 inches in diameter by 6 feet high and are operated in series.

PILOT PLANT RESULTS

Pure Lactose Solutions

Pure lactose solutions at various concentrations and temperatures were processed through the pilot-plant reactors to provide baseline hydrolysis data not subject to extraneous effects such as whey-protein adsorption for comparison with similar data obtained during bench-scale experiments. Results of a typical experiment are given in Figure 5. Operating conditions are specified in the figure. It should be noted that deviation from steady-state conversion in this experiment was unquestionably associated with reactor start up. These results are quite encouraging in that for the same catalyst (lactase adsorbed on alumina and cross-linked with glutaraldehyde) and the same normalized reactor residence of 5.07×10^4 LU-min/ml the conversions of 5% lactose solutions were 65% in the bench-scale reactors (1" diameter)(1,2) and 84% in the pilot plant reactor: The enhanced conversion at the pilot scale is believed to be a result of better flow distribution in the larger reactors. Such better flow distribution may be partially inherent in the scale-up and may also result in part from improved distributor design. The bench-scale reactor distributor was a modified bubble cap(2) which produced visible channeling while the reactor distributor is simply a conical inlet section as previously discussed. A comparison of results and operating conditions for bench and pilot scale is given in Table 1.

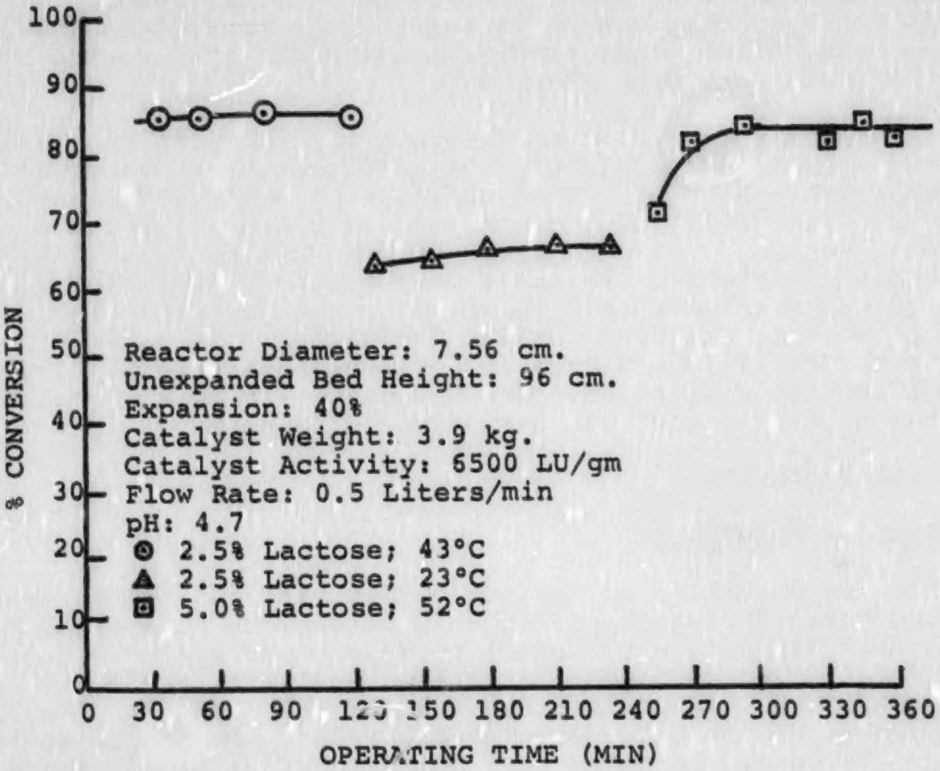

Figure 5. Hydrolysis of Lactose Solutions in Pilot Plant Reactor.

TABLE 1. COMPARISON OF PILOT PLANT AND BENCH SCALE RESULTS FOR HYDROLYSIS OF LACTOSE SOLUTIONS

	Bench Scale	Pilot Plant
Reactor Diameter (cm)	2.54	7.56
Unexpanded Bed Height (cm)	10.00	96.00
Expansion (%)	60%	40%
Catalyst Weight (gm)	50	3900
Catalyst Activity (LU/gm) (1)	4400	6500
Residence Time (LU-min/ml) (2)	507×10^2	507×10^2
Lactose Concentration (wt.%)	5.0%	5.0%
Flow Rate (liters/min)	0.06	0.50
Conversion (%)	65%	84%

(1) Catalyst Activity Assayed At 37°C

(2) Based On Catalyst Activity At 37°C

Whey Permeate & Raw Whey

Initial experiments were conducted in which whey was first ultrafiltered and subsequently hydrolyzed. Results for conversion of lactose in whey permeate as a function of time are given in Figure 6. The initial unsteady-state is associated with reactor start-up.

The reactor has not as yet been operated with this feed-stock for a sufficient period of time to observe the effects of catalyst deactivation.

The results of experiments in which raw, unfiltered whey was fed directly to the hydrolyzer are presented in Figure 7. (The numbers attached to the data point are average reactor temperatures; some difficulty was experienced in maintaining constant temperature during these experiments.) It will be noted that in addition to the unsteady-state associated with start up there is a slow but discernable decrease in conversion which can not be completely explained by the temperature variations experienced. Furthermore, an increase in activity (and hence enhanced conversion) was observed directly after the catalyst bed was sanitized with Iosan. (The sanitization operation involves washing the bed in the expanded state for approximately 1 hour.) However, this increase was lost soon after the feed of raw whey was started

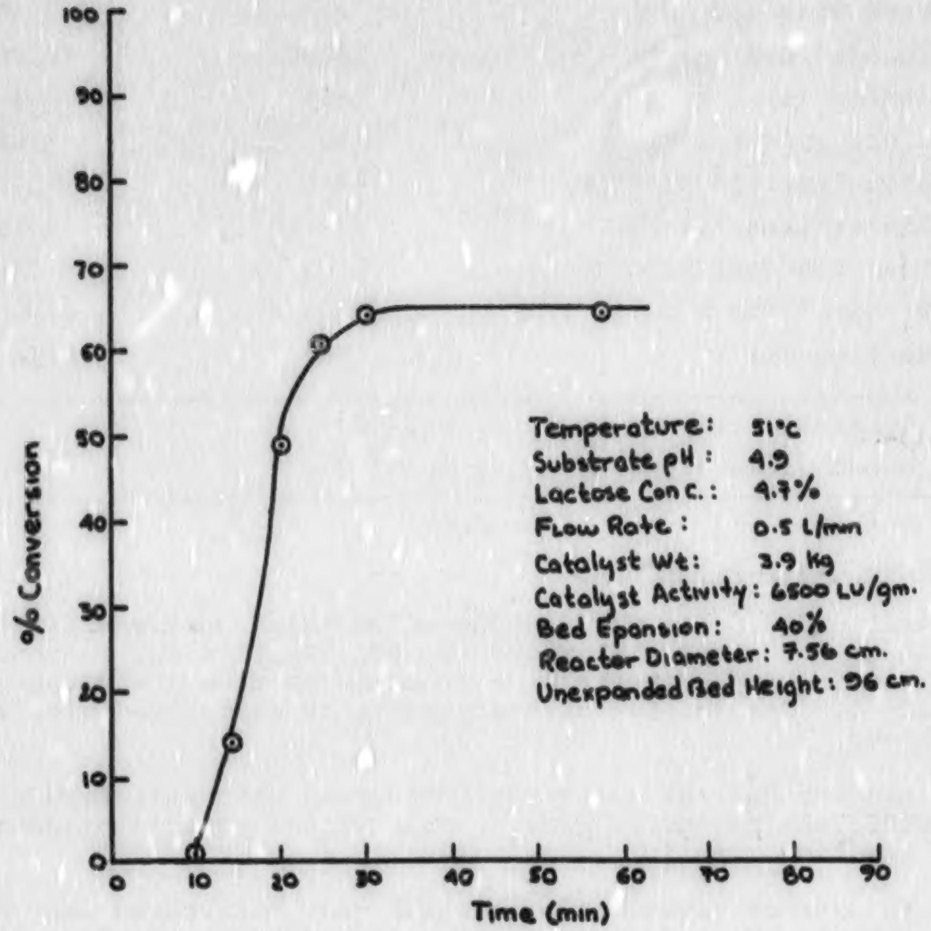

Figure 6. Hydrolysis of Whey Permeate in Pilot Plant Reactor.

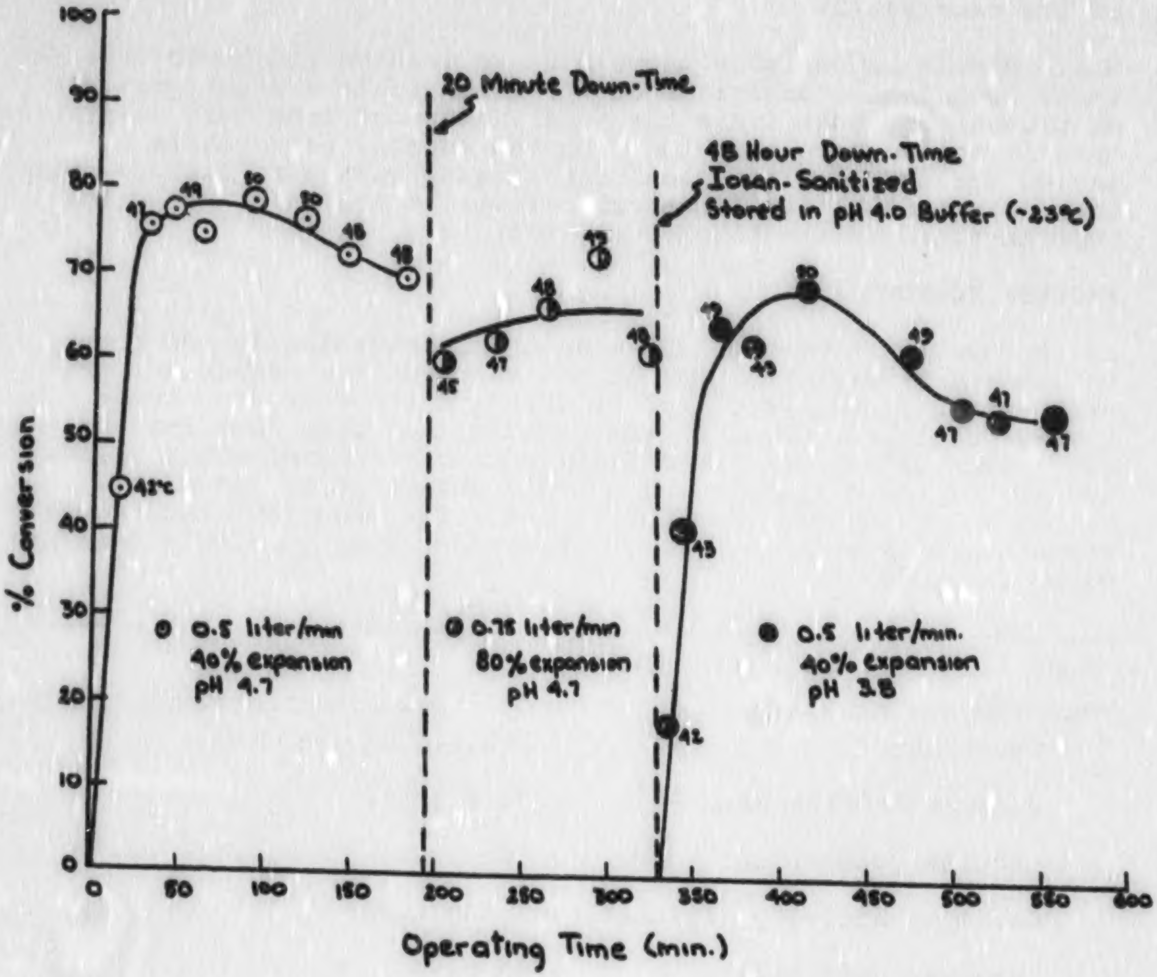

Figure 7. Hydrolysis of Raw Whey in Pilot Plant Reactor.

again and the slow decrease in conversion continued. This is the same behavior exhibited at the bench scale and is consistent with our theory that rapid adsorption of whey protein causes step changes in activity to be superimposed on the natural decay of the catalyst(2).

While direct comparisons between these results and those obtained under comparable conditions at the bench scale are not possible at present and must await the accumulation of long term on-stream data it now appears that the improved reactor performance observed during the pilot plant experiments with pure lactose solutions promises better long-term results at the pilot scale than were obtained at the bench scale with whey.

PROCESS ECONOMICS

At the present time the only meaningful determination of return on investment must be based on the value of the components present in the final hydrolyzed product and the waste treatment savings realized. Such a determination has been done for the conversion of raw whey to a final product containing 50% solids and all of the original whey protein and in which 70% of the original lactose has been hydrolyzed. The main features of the calculation(2) which are based on bench-scale hydrolysis data are given in Tables 2, 3, and 4.

TABLE 2. BASIS OF COST CALCULATIONS

Throughput	: 100,000 Whey lbs/day
Volumetric Flow Rate	: 34.4 ℓ/hr.
Lactose Conversion	: 70%
Catalyst Activity (Initial)	: 3,500 LU/gm
Catalyst Half-Life	: 60 days
Total Catalyst Required	: 710 kg
Reactor Diameter	: 20 in. (50.8 cm)
Reactor Height	: 22.5 ft. (6.86 m)

TABLE 3. CAPITAL AND OPERATING COSTS

Equipment	$101,000.00
Catalyst	$15,110.00
Operating	$371.00/day (Incl. Catalyst)
Fixed	$70.00/day
Total For Hydrolysis	9¢/lb. Whey Solids
Demineralization	2¢/lb. Whey Solids
Concentration (50% Solids)	4¢/lb. Whey Solids
Total	15¢/lb. Whey Solids

TABLE 4. RETURN ON INVESTMENT

Value of Added Sweetness Based on Sucrose @21.25¢/lb.	8.64 ¢/lb. Whey Solids
Value of Whey Protein Based on 50¢/lb. Protein	8.14 ¢/lb Whey Solids
Cost of Waste Treatment Based on 40,000 mg O_2/kg Whey and 5¢/lb. BOD	4.07 ¢/lb. Whey Solids
Total Value	20.85 ¢/lb. Whey Solids
Return On Investment	5.85 ¢/lb. Whey Solids or ~68% for 300 day/year operation

The calculated return of 68% is quite encouraging particularly in light of the fact that the pilot plant hydrolyzers appear to be more efficient than the bench scale reactors. However, it is important to recognize that a truly realistic evaluation of ROI must be based on the market value of the product itself and not on the values of individual components (although this will not effect waste treatment savings which constitute almost 20% of the calculated product value). A determination of this market value must await the results of product testing by prospective users.

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IN-PLANT CONTROL TECHNOLOGY FOR THE FRUITS AND VEGETABLES PROCESSING INDUSTRY

by

Kenneth V. LaConde* and Curtis J. Schmidt*

During 1974, SCS Engineers, under contract with the Environmental Protection Agency, conducted a nationwide study of the preserved fruits and vegetables processing industry to develop effluent limitations guidelines. Throughout 1975, additional work to investigate, identify, and describe current in-plant technologies was performed for this same agency.

Initially, in 1974, approximately 500 processing plants representing 58 subcategories were visited to obtain the following:

1. Basic manufacturing processes and unit operations.
2. Wastewater volume and characteristics. Wet sampling was performed at selected plants to both verify and expand the data base.
3. Current in-plant practices utilized to reduce wastewater volumes and pounds of pollutants (BOD and SS).
4. Current treatment technologies, performance efficiencies, alternatives, and costs.

All data received, after careful screening, was placed in a computer bank, the output of which resulted in plant and subcategory averages. These data were in turn recycled through the individual companies to be verified for accuracy. Comments were subsequently received and the data, wherever necessary, modified. Additionally, new input was also received from the current processing season (1974) to expand the existing data base. All of these information points were then, once again, entered into the computer. This resulted in the final data base which EPA subsequently used to develop the effluent limitations guidelines as promulgated on October 21, 1975. The work effort of SCS Engineers relative to in-plant control technologies utilized this final data base as a starting point.

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*SCS Engineers, Long Beach, California and Reston, Virginia

In-plant controls are usually the most effective way to reduce waste load generation in fruit and vegetable processing plants. These alone cannot accomplish the required effluent discharge limitations, but they can reduce the waste load by a factor well over 50 percent, reducing the cost of city discharge or waste treatment accordingly. In-plant controls not only reduce the waste load, but are also employed to improve processing efficiency and product quality. Nearly all of the 500 plants visited could have improved their in-plant control and water conservation measures.

The first task at hand was to define those subcategories to be investigated. Each of these were reviewed in terms of wastewater volume, pounds of BOD and SS generated, and size of pack. Concurrent with this, further development of the economic study necessitated review of certain specific subcategories.

From a combination of the above factors, the following subcategories were finally chosen for investigation: canned apricots, brined cherries, sour cherries, sweet cherries, caneberries, dried fruit, canned peaches, canned pears, canned plums, strawberries, baby food, canned asparagus, canned dried beans, canned beets, canned corn, frozen corn, canned and frozen carrots, mushrooms, canned peas, frozen peas, fresh pack pickles, processed pickles, sauerkraut canning and cutting, frozen spinach/greens, canned spinach/greens, canned snap beans, frozen snap beans, sweet potatoes, tomato products, peeled tomatoes, and potato chips.

Each of the individual data points which comprised the computed averages were then carefully examined. Previous computer runs had expressed each of the reported data points in terms of flow, BOD, and SS. All results, except as otherwise noted, were expressed in terms of raw product received. Further, within each subcategory, arithmetic and log averages were computed using both individual data points and individual plant averages. This defined individual plant performances and afforded an opportunity to compare the waste parameters from various plants within each subcategory.

Those plants which exhibited significantly lower raw waste loads than the average were identified, and the data carefully re-examined. The emphasis of this examination was placed on those in-plant controls and/or technologies which were positively identified as a contributing factor to the reduced raw waste loads.

This resulted in a list of plants to be investigated in more detail.

As previously mentioned, the majority of information relative to individual plant operations had been gathered throughout the 1974 contract period. It was, therefore, necessary at this time for a third review of all information on hand. The scope of this examination involved the following:

- Examination of the various in-plant unit processes and their potential effect on pollutants generated.

- Comparison of these individual operations to other plants within the same category.

- An evaluation of the observed unit process differences and their significance to the performance averages.

- Relationship of product styles, size of container (industrial vs. retail pack) and other similar variables to waste load differences.

- The formation of various questions to clarify what particular steps or operations these plants possessed that enabled them to produce a significantly lower waste load.

This list of questions was further and more completely developed to lend input to existing in-plant qualitative information. This checklist, referred to as the In-Plant Control Check Sheet, encompassed the basic unit processes for a majority of fruit and vegetable preservers. These were raw product cleaning, product conveyance, peeling, blanching, product cooling, canning, waste handling, and cleanup.

The plants were also asked to detail other conservation systems not covered by the check sheet. Additionally, they were requested to lend input to waste management philosophy within their respective companies. For example, who is responsible for waste control within the respective processing plants? In what terms are equipment modifications considered? In terms of water use reductions? Improved case yields? Labor savings? Energy/chemical savings? All of these? Other considerations? An additional question concerned the use of by-products. Are any useable by-products generated from any specific equipment that was installed for pollution abatement purposes? Further, are any revenues received from these by-products to help off-set the cost of this equipment?

Upon receipt of the completed forms, the individual plant comments were compared to the original plant visit information files. Additions or corrections, where appropriate, were made. As a further step to better delineate the unit processes, follow-up phone calls were made for more detailed clarification. This point in time, then, represented the most current and complete data bank gathered throughout the contract period.

By and large, the results of these examinations were not surprising. Each of those plants responding had taken positive action in one way or another to reduce their waste loads. Taken as a whole, certain unit processes and/or technologies were readily identified as having an impact on raw waste load reductions. Among these were:

- Separation of low and high strength waste streams
- Installation of low-volume high-pressure cleanup systems
- Dry in-plant transport of products
- Countercurrent reuse of wash/flume/cooling waters
- Dry handling of solid wastes
- Dry caustic peeling
- Changeover from water to steam blanching (where possible)
- Air cooling after blanching
- An active and progressive waste management program

As a result of this current work, we would like to present one case study to illustrate what can be achieved by progressive and conservation-minded management. Technologies that will be discussed are: separation of waste streams, blanching, air cooling, solid waste handling, and waste management.

CASE STUDY

Plant "A" is a processor of frozen carrots. The plant operates on a typical schedule of 5 days per week, 10 to 11 months each year. Normal production is set for two shifts per day with additional cleanup time as needed. Average throughput is approximately 8 raw tons per hour.

Figure 1 is a flow diagram of this plant's operation prior to 1974. As can be seen, the manufacturing processes were quite typical. Carrots were delivered in bins either directly from the field or from a fresh sorting shed. They were washed, trimmed, conventionally lye peeled and diced or sliced. Blanching was accomplished by means of a water blancher; post blanch cooling was by water. Water usage was high with a daily average approaching 1.5 mgd. BOD levels were similarly high averaging about 2400 mg/l.

This plant, landlocked by city growth, was already paying a surcharge for its effluent disposal, but the city, recognizing that expansion was needed for industrial users, initiated discussions for a revised surcharge system. Tentative proposed surcharge formulae indicated that if this system was adopted, monthly discharge rates could approach $4,000.

At this point, corporate management decided to institute changes in the form of capital investments. The engineers, when designing the modifications considered each waste contributing point within the processing sequence. Figure 2 shows the results of these efforts; Table 1, the benefits.

Carrot Washing

Water used to wash the incoming carrots had previously been combined with the main plant effluent stream. However, observation and testing of this stream indicated that its chief components were sand and dirt, some field debris, and occasional carrot particles. Becuase of the plant's location, they decided to isolate this stream from the higher concentration waste streams and discharge it separately under NPDES permit. A double screening system was installed (not shown on diagram) to effectively remove the various solid particles from the waste stream. This not only lowered the suspended and settleable solids but also in part, contributed to reduced BOD discharge. Freezer defrost water was also diverted to merge with this stream.

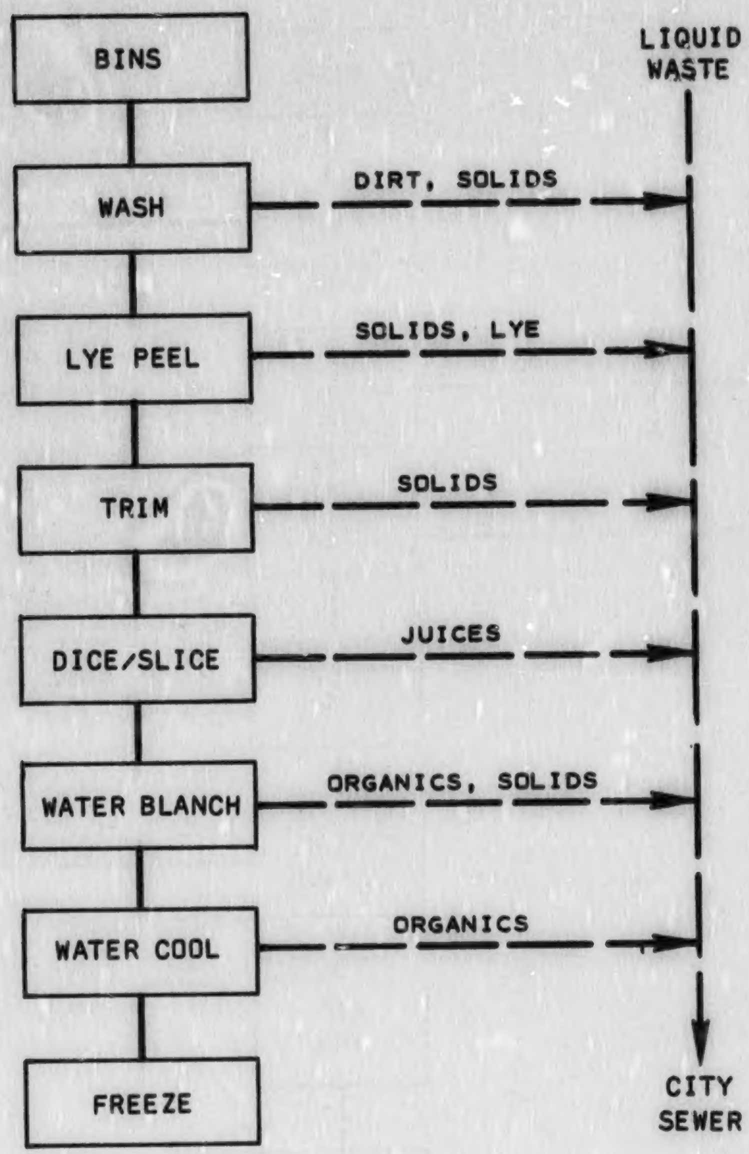
BINS
WASH
LYE PEEL
TRIM
DICE/SLICE
WATER BLANCH
WATER COOL
FREEZE
LIQUID WASTE
DIRT, SOLIDS
SOLIDS, LYE
SOLIDS
JUICES
ORGANICS, SOLIDS
ORGANICS
CITY SEWER

FIGURE 1. ORIGINAL FLOW, CARROT PROCESSOR "A"

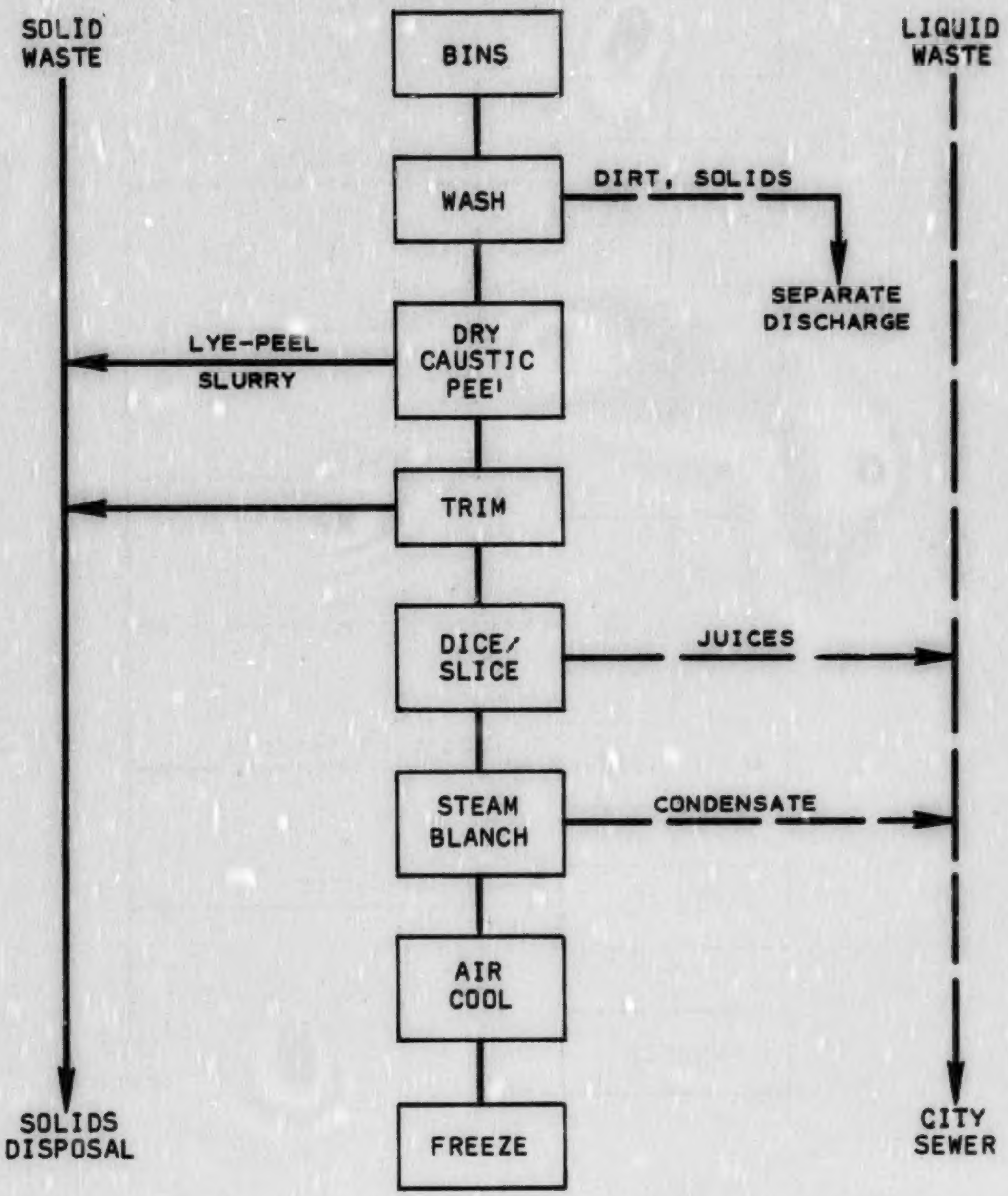
SOLID WASTE
BINS
LIQUID WASTE
WASH
DIRT, SOLIDS
SEPARATE DISCHARGE
LYE-PEEL SLURRY
DRY CAUSTIC PEEL
TRIM
DICE/ SLICE
JUICES
STEAM BLANCH
CONDENSATE
AIR COOL
SOLIDS DISPOSAL
FREEZE
CITY SEWER

FIGURE 2. MODIFIED FLOW, CARROT PROCESSOR "A".

The effect of this separation should not be underestimated. These two components are responsible for approximately 60% of the total plant flow - about 350,000 gallons per day. The alternative discharge of this large volume of water to a city sewer system would have been extremely expensive.

Peeling

The peeling process was identified as the main source of BOD and SS generation. The water required for peel removal was a substantial percentage of the plant's total effluent. A new lye peeler (ferris wheel type) was purchased and installed.

The conventional high pressure water lye peel removal system was replaced with a Magnuscrubber. The resultant peel waste slurry was pumped directly to a holding tank. Ultimate disposal of this waste fraction is to a sanitary landfill.

Table 1. Carrot Process "A." Parameter Differences

Parameter	Before	After
Flow (MGD)	1.5	0.6[1]
Flow Ratio (Gal/Ton)	9375	3750
BOD (mg/l)	2400	1600
Sliced Recovery (%)	50	62
Diced Recovery (%)	65	72
Monthly Surcharge ($)	4000*	500

* Estimated

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[1] 0.35 MGD discharged under NPDES permit, 0.25 MGD to city

Note that in addition to the expected water usage and BOD reductions, finished product recoveries increased for both sliced and diced. These increased yields are a direct result of the new peel removal system. Although numbers were not available, the plant personnel were also aware of a reduction in caustic soda consumption.

Dry Solids Handling

The plant engineers recognized that every attempt should be made to stop the introduction of solid wastes into the effluent stream. The original plant flow allowed for trimmings and solid waste to be flushed into gutters with final screeing before discharge to the city sewer system. This allowed for additional leaching of soluble solids and was, in part, responsible for the plant's high BOD. To overcome this problem, a separate series of dry solids conveyors were installed to transport trimming table and other wastes directly to outside waste bins. Further, a concerted effort was made by management to instruct plant employees on proper methods of solid waste handling.

Blanching

As shown in Figure 1, a hot water blancher had been used over the years.

Enzyme deactivation and product quality met the necessary criteria for continued use. Water blanchers, however, have been shown to be a major source of water pollution. The action of solids leaching, continuous spillage and overflow contribute heavily to a plant's BOD and SS loads. The waste stream is not only concentrated, but is of substantial volume. The old water blancher was removed and a stream blancher was installed. The only effluent from this unit process is a highly concentrated 1-2 gpm condensate. The effect on total BOD and SS load has been considerably lessened, yet the desirable quality characteristics retained.

Cooling

Similarly, post blanch hydrocooling necessary to prepare carrots for freezing and to optimize freezer efficiencies was determined to be a contributor to the plant's effluent load - to eliminate the flow altogether was the objective. The conventional hydrocooling system was replaced with an ambient air cooler. Working on a fluidized bed principal, the product exits the blancher and is blown and vibrated over perforated screens by the action of air jets blowing through and upward to contact the product. The action of the air and the mechanical vibrations of the screen move the product across the screen during which the required cooling gradient is achieved. The use of air eliminates almost all water contact after blanching except for one or two fine water sprays between the blancher and cooler. Water usage at this stage was estimated at no more than 2 gals/minute.

Capital Investment

The plant estimates their total expenditure for all the improvements and modifications to be approximately $90,000. Although no attempt was made to calculate paybacks on investment capital, it can be seen in Table 1 that savings accrued due to reduced discharged volume and pounds of pollutants to the city accounts for approximately $42,000 per year. If one were to add a monetary value to the increased yields, the investment looks even more attractive.

Waste Management

We have briefly reviewed the components of a revised, modified and updated carrot processor. We have alluded to an active management role and corporate confidence in terms of capital invested. One personal observation should be added at this point. All of the employees seemed to be cognizant of management's attempt to reduce both solid and liquid wastes. The plant was a model of cleanliness. They all appeared involved, concerned and willing to do their share to help management achieve its goals.

LAND DISPOSAL OF WINERY WASTEWATER

by

Dr. Larry L. Russell*, Dr. John N. DeBoice*, and
Dr. Walter W. Carey**

INTRODUCTION

A wastewater treatment and disposal system has been constructed recently for the Beringer Winery in St. Helena, California. The treatment system consists of screening and neutralization prior to disposal of the wastewater to seven percolation beds. The wastewater flow is usually less than 50,000 gpd and the Chemical Oxygen Demand (COD) of the wastewater can be 10,000 mg/l or more.

The land disposal system was chosen because it provided the highest level of treatment for the least capital and operating costs. The nuisance problems, such as odors and gnats frequently associated with winery wastewater treatment, are completely controlled by applying the wastewater to the soil at a rate sufficiently low to ensure that aerobic conditions are maintained in the soil. Additionally, a very high level of treatment would be required prior to discharge to a surface water, and the costs would be excessive.

A study of the effects of the disposal system on the ground water quality was conducted prior to initiating discharge. The study consisted of a computer simulation of the chemical and biological reactions that occur in the soil in conjunction with a dispersion analysis. The study showed that land disposal of the wastewater was feasible and that the effects on the ground water quality would be minimal.

An ongoing monitoring program consists of analyzing samples taken from observation wells located upstream and downstream of the percolation beds. In this manner, the quality of the ground water is monitored, and changes would be observed prior to any significant impact on the ground water.

BACKGROUND

The construction of a large new winery at the Beringer Winery site required the design of a new wastewater treatment and disposal system. In a previous study at another Beringer Winery, the wastewater generation

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*James M. Montgomery, Consulting Engineers, Inc., Walnut Creek, California
**The Nestle Company, White Plains, New York

varied from 200-300 gallons per ton of grapes crushed. Using this information, the system was designed to treat and dispose of about 50,000 gallons per day (gpd) during the crushing season, which normally extends for 45 days in the fall. The wastewater flow rate decreases to about 20,000 to 30,000 gpd during the noncrushing season.

Several alternative treatment systems were considered, such as aerated ponds, high-rate biological oxidation and percolation beds. A review of the literature conducted by Stokes(1) indicated that the most reliable means of treatment was the use of percolation beds, and that nuisances such as odors would be completely controlled by proper operation and wastewater application. A recent survey conducted for the Environmental Protection Agency(2) indicated that approximately 80 percent of the wineries in the United States depend on land treatment by either aerated ponds or percolation beds. The remainder of the wineries utilize municipal treatment systems.

After considering the alternatives, the use of percolation beds was evaluated in detail because a high level of treatment could be obtained for low cost. The soils in the area of the winery are coarse alluvial materials underlain at about 25 feet by a clayey sand. Percolation tests were conducted at the chosen location; the soil exhibited percolation rates of 10-20 feet/day which would easily accommodate a loading rate of 100,000 gal/acre/day proposed by Coast Laboratories in 1948(3). This loading rate results in a depth of application of about 4 inches. The soil should be allowed to dry thoroughly (approximately 6 days according to Coast Laboratories) prior to the application of more wastewater. The intermittent application of the wastewater ensures that aerobic conditions are maintained and that the biological growths, which act to "blind" the soil and reduce its percolative capacity, will be controlled by the drying out periods.

Permeability studies conducted on the coarse alluvial soils showed that the soil was quite permeable, having permeabilities in excess of 2,000 gal/day/sq. ft. The hydraulic gradient is such that the Darcy velocity is about 3 feet/day.

During the planning stages of this study, a computer simulation was conducted of the biological and chemical reactions that occur in the soil. The model, described in detail by Russell(4,5), is capable of accurately predicting the quality of a percolating water applied to a soil for treatment and disposal. The simulation indicated that a hardness, alkalinity, and TDS pickup of up to 400 mg/l (hardness and alkalinity expressed as $CaCO_3$) would be experienced due to the dissolution of the calcite in the soil by the CO_2 produced as a result of the biological oxidations of the organic material.

The results of the computer simulation were used as inputs to a dispersion analysis; and the effects of the discharge on the receiving water, the Napa River located 2,000 feet from the percolation beds, were evaluated. Figure 1 shows a cross section of the aquifer and the projected area of influence denoted as the plume. The steady state operation of the treatment and disposal system would result in an estimated increase in the TDS of the ground water of about 200 mg/l.

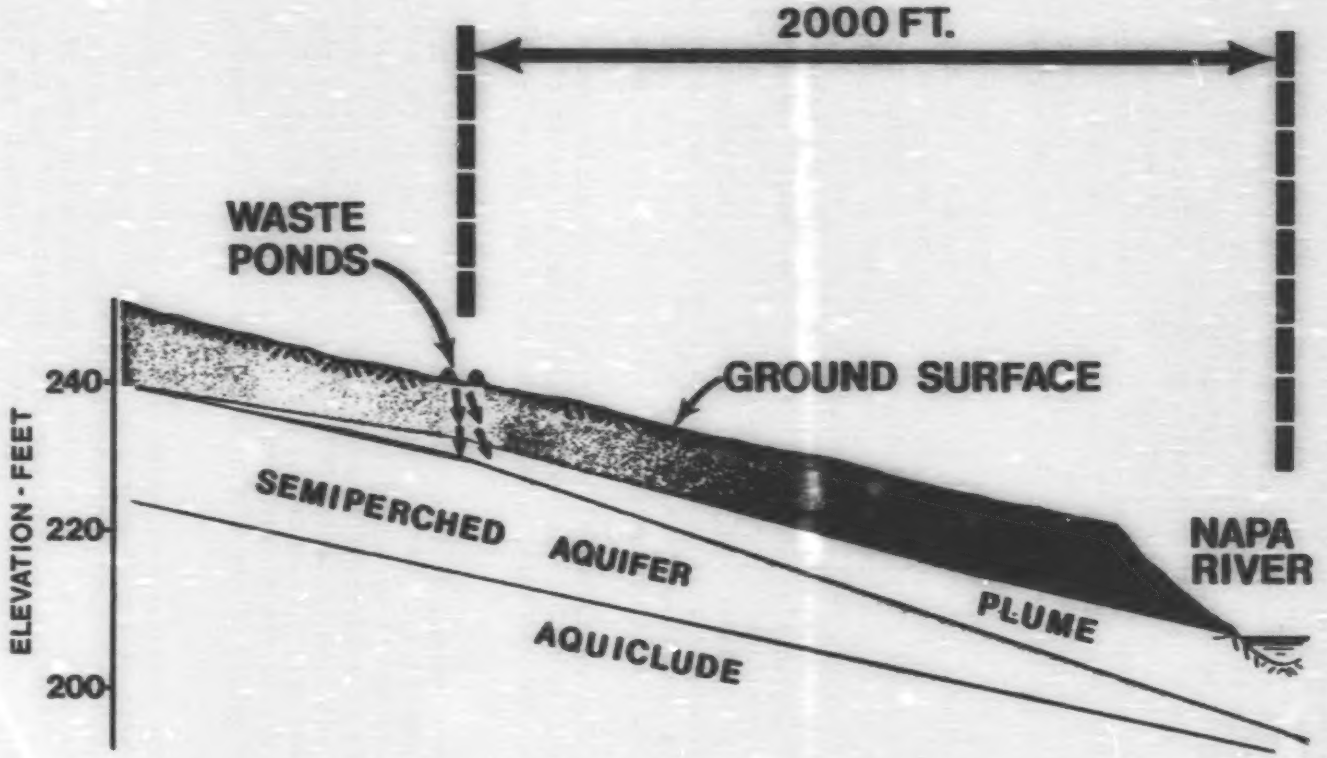
2000 FT.
WASTE PONDS
GROUND SURFACE
NAPA RIVER
240
220
200
ELEVATION - FEET
SEMIPERCHED AQUIFER
PLUME
AQUICLUDE

FIGURE 1: CROSS SECTION OF THE AQUIFER

The ground water in this aquifer is not used for irrigation or domestic purposes. The entire ground water flow joins the Napa River; and as long as the TDS change is within the range indicated by our studies, the effects of the discharge are minimal.

Figure 2 shows the layout of the percolation beds and their orientation relative to the movement of the ground water. There are seven percolation beds, as shown in Figure 2, and the wastewater is applied to a different bed each day to allow the beds to dry and to ensure that aerobic conditions are maintained. The new winery is located to the southwest of the percolation beds, and the Napa River is located about 2,000 feet from the percolation beds in the direction of the ground water movement.

The wells are denoted by the letters "U", "N", "M", and "S." The well marked "U" is the upstream well, and the other wells denoted "N", "M", and "S" are the north, middle, and south wells. These wells are used to monitor the quality of the ground water on a monthly basis during the crushing season and a quarterly basis during the rest of the year.

WASTEWATER CHARACTERISTICS

The wastewaters generated during the production of wine are primarily from the washing and cleanup of the fermenters and storage tanks. Significant quantities of inorganic solids such as bentonite and diatomaceous earth are used in the "racking" or fining of wines, and these inorganic solids combine with the organic solids removed from the wine to form a sludge at the bottom of the tanks. Most of the organic material in the wastewater is biodegradable.

Most of the data in the literature on winery wastes concerns wastes that contain stillage. Very little data has been reported on non-stillage winery wastewaters. The Beringer Winery has no stillage wastes, and the treatment system was designed on the basis of a small amount of data collected at another Beringer Winery and the limited data in the literature. A comprehensive sampling program was initiated to provide the data to characterize the wastewater and to ascertain that the treatment system was suitably designed for the wastewater.

Samples were taken by an automatic sampler every one and one-half hours for a period of two months. Four samples were deposited in the same bottle to form a six-hour composite sample. Half of the six-hour samples were preserved with sulfuric acid and the other half were preserved with mercuric chloride. The samples preserved with sulfuric acid were analyzed for hardness, calcium, TDS, COD, and total Kjehdahl nitrogen (TKN). The remaining samples were analyzed for alkalinity, pH, conductivity, and odor.

The results of the sampling program are shown in Table 1. Note the large amount of variation in the concentration of these constituents. The values reported are average daily concentrations. The variation in the results is due to the batch nature of the cleaning operations. The minimum

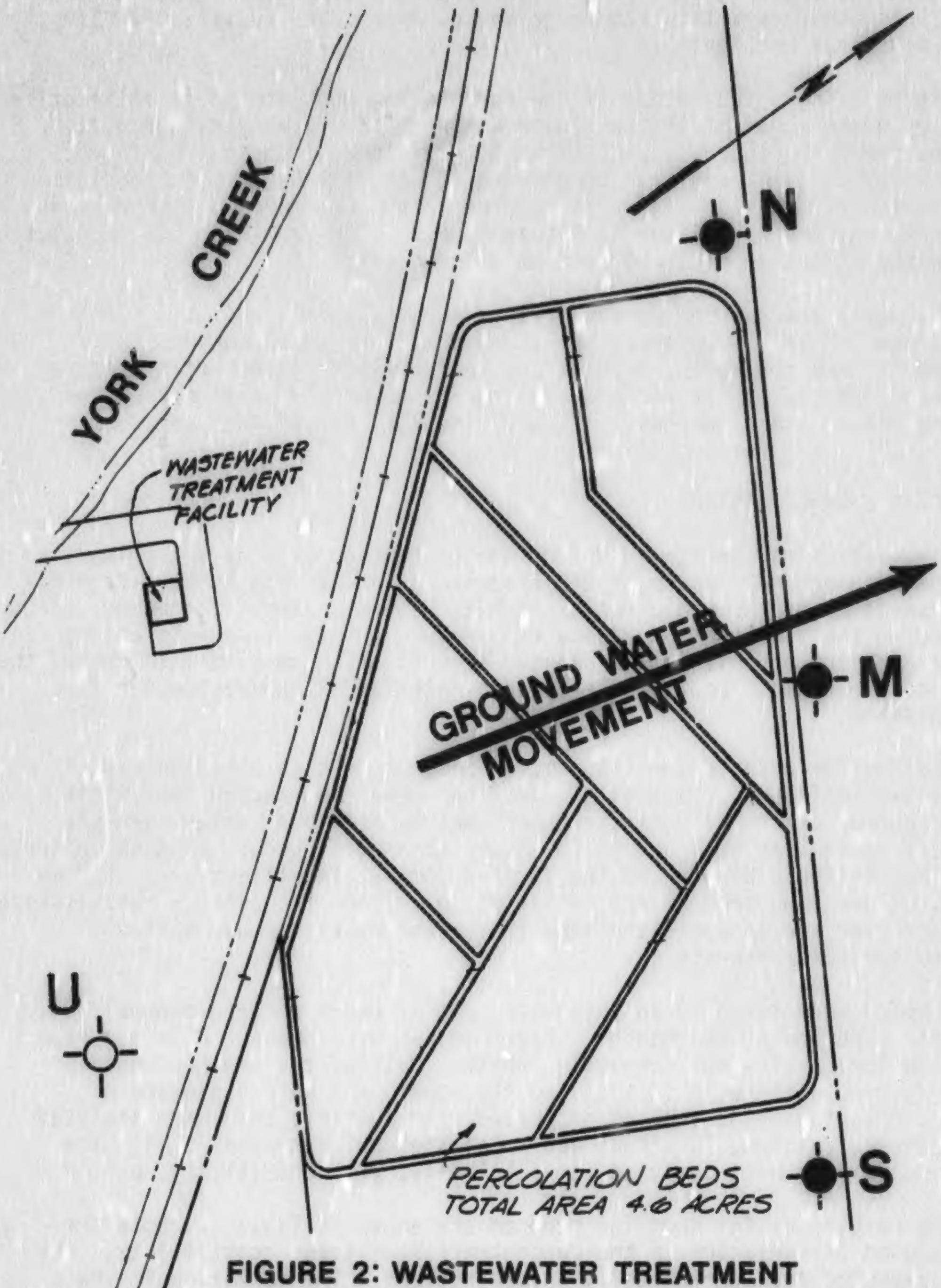
YORK CREEK
WASTEWATER TREATMENT FACILITY
N
GROUND WATER MOVEMENT
M
U
S
PERCOLATION BEDS TOTAL AREA 4.6 ACRES

FIGURE 2: WASTEWATER TREATMENT AND DISPOSAL SYSTEM LAYOUT

values reported for the hardness, TDS, and COD reflect the concentrations found in the cooling water, which amounts to 10,000 pgd.

TABLE 1. WINERY WASTEWATER QUALITY (Non-crushing Season)

	Hardness* mg/l	Alkalinity* mg/l	TDS mg/l	COD mg/l	pH	TKN mg/l
Mean	185	284	870	2,950	6.5	12.5
Max	580	1,070	2,000	25,700	9.7	74.5
Min	80	0	200	100	3.9	1.2

*as $CaCO_3$

The samples rarely had any foul odor; most of the odor was due to wine, and the odor of the wastewater was not unpleasant.

GROUND WATER QUALITY

One stipulation of the discharge permit was that the ground water quality would be monitored by ovservation wells located up and downstream of the percolation beds. This phase of monitoring has been conducted since the fall of 1974. The ground water monitoring program was supplemented during the wastewater monitoring period by taking additional samples weekly. The samples were preserved by refrigeration and the analyses were conducted as soon as possible.

The upstream water quality data is presented in Table 2. Note the rather high COD of 45 mg/l, which reflects the use of the aquifer as a receiving water for wastewaters from sanitary drain fields and from previous wastewater disposal practices.

TABLE 2. UPSTREAM GROUND WATER QUALITY

Hardness* mg/l	Alkalinity* mg/l	TDS mg/l	COD mg/l	pH
185	180	300	45	6.9

*as $CaCO_3$

The downstream water quality data is shown in Table 3. The wells are identified as noted in Figure 2. The bulk of the effect of the discharge is seen in the middle well ("M"), as would be expected from the dispersion pattern that results from a line source discharge, such as the percolation beds. Note the small effect of the discharge on the COD of the ground water; a significant fact in light of the large COD concentrations found in the wastewater. The hardness, alkalinity, and TDS pickups are less than the maximum concentrations predicted by the computer simulation and the dispersion analysis, which most likely reflects a more rapid and thorough outgassing of the CO_2 at the soil surface during the drying period than was anticipated. As more CO_2 is outgassed, the ability of the wastewater to dissolve calcite is reduced.

TABLE 3. DOWNSTREAM GROUND WATER QUALITY

Well	Hardness* mg/l	Alkalinity* mg/l	TDS mg/l	COD mg/l	pH
N	300	260	340	35	6.3
M	425	470	370	65	6.7
S	240	315	315	40	6.8

*as $CaCO_3$

SUMMARY AND CONCLUSIONS

The installation of the treatment and disposal system at the Beringer Winery has been an unqualified success. The percolation beds have been in use for nearly one full season, and the effects on the quality of the ground water have been minimal. No odor or nuisance problems have occurred and the percolation beds have been operated with a minimal amount of energy and manpower. The intermittent loading practice has resulted in a manageable and efficient wastewater treatment system.

The soil type and ground water gradient have combined to make an ideal situation for a wastewater disposal system of this nature. The high rate of percolation has been maintained throughout the period that the percolation beds have been in operation. The quantities of inorganic and organic suspended solids applied to the percolation beds have not significantly affected the percolation bed operation.

The impact of this treatment system on the environment has been minimal. This system is a good example of the integrated approach to wastewater treatment wherein an effective treatment system has been developed that combines energy conservation with the maintenance of high standards of environmental quality.

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LOW WASTEWATER POTATO STARCH/PROTEIN PRODUCTION PROCESS - CONCEPT, STATUS, AND OUTLOOK**

by

J. R. Rosenau*, L. F. Whitney*, and R. A. Elizondo*

ABSTRACT

A process for producing starch, feed grade protein meal, and pulp from cull potatoes with minimal water use has been developed and is being "tuned". Potatoes are ground and wet sieved to remove pulp. Recycled juice is used in the sieving process to flush starch from the pulp. The pulp, after pressing or centrifuging to remove residual juice, is dried. The starch-juice mixture is passed through an elutriation type liquid cyclone yielding a starch-rich underflow and a starch-free juice overflow. The use of low-volume elutriation in the cyclone minimizes protein and fiber in the starch underflow which is dewatered and washed in a vacuum filter (or basket centrifuge), dried and ground. Air classification of the dried starch further reduces impurities and improves whiteness.

A bleed stream from the recycled juice removes the protein introduced by the potatoes. This juice, which contains 4% solids (w.b.) and 50% protein (d.b.), is concentrated and dried. The use of ultrafiltration, or heat and acid induced precipitation, to concentrate and fractionate juice solids is currently being investigated.

INTRODUCTION

Research relating to food processing wastes can, in most cases, be divided into three areas: treatment of food processing wastes, process modification to reduce waste loadings, and by-product recovery. Of these, the last areas are often the most exciting from a plant operation standpoint since they usually can be implemented at a profit.

Cull potatoes have been processed for starch and pulp for many years.(1,2,3,4,5) Traditionally, starch processing has included grinding

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*Department of Food and Agricultural Engineering, University of Massachusetts, Amherst, MA 01002.

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(in the presence of SO_2 which retards browning) and wet sieving with an excess of water to separate starch from pulp. The pulp is dewatered by pressing or centrifuging and dried in a rotary drier for cattle feed. The starch is refined, originally by settling or tabling, more recently, by centrifugal or multistage liquid cyclone systems. Vacuum filtration or basket centrifugation is used for final starch dewatering prior to drying, grinding and bagging.

Non-starch constituents washed from starch granules give rise to large BOD loadings in the effluent streams, and many starch processors have been forced to close because waste processing systems capable of handling the discharges are prohibitively expensive. Pollution problems have played an important part in the closing of over twenty plants in the New England area alone.

The closing of these plants has lead to additional problems. Culls have been dumped into landfills or back onto the growers' fields (which leads to potential disease propagation). Meanwhile, the price of potato starch has climbed to about 13¢ per pound.

Strolle, et al (6) outlined processes for the recovery of protein from effluent streams by heat and acid precipitation. Potato processors in the Netherlands(7) currently are extracting protein by similar methods from effluent streams. They have also used nine-effect vacuum evaporation systems to handle the voluminous discharges involved(8). Stabile, et al(9) have also investigated vacuum evaporation and drying of dilute potato juice.

The work summarized by this paper has lead to a process that produces starch of a quality nearly equal to that produced by current production systems but with the incorporation of only 25 pounds of water for every 100 pounds of potatoes processed.

FIRST GENERATION PROCESS

The flow sheet shown in Figure 1 summarizes initial attempts to minimize water usage in starch production. As shown, potatoes were ground with sulfite (1000 ppm SO_2) through a screen with 1/16 inch diameter holes in a hammermill. The slurry was dewatered in a decanting centrifuge, dried, ground, sieved through a 200 mesh screen to remove peel fragments, and air classified to remove fines. As an option, the cake leaving the centrifuge was slurried with varying amounts of wash water and recentrifuged.

The process was implemented with a Pfaudler ZIL decanting centrifuge and an Alpine American 100 MZR air classifier. The cleanest starch made with the process (using 40 pounds of wash water per 100 pounds of incoming potatoes) tested 1.2% protein (d.b.) and had an Agtron reflectance reading of 75%. In comparison, commercial potato starch produced by conventional methods is about 95% reflectance and has only traces of protein.

Inspection of the air classified starch under a magnifying lens revealed

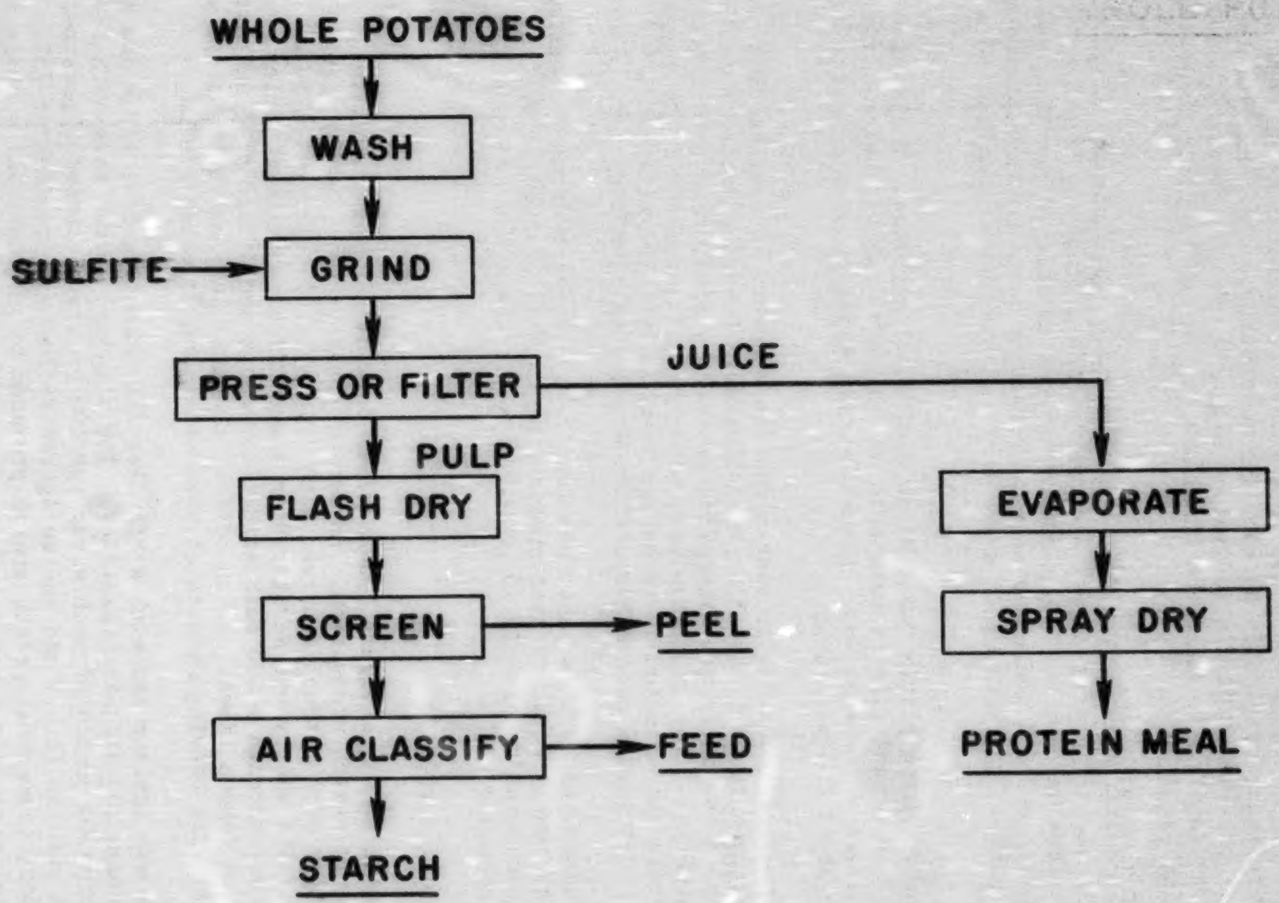
WHOLE POTATOES
WASH
SULFITE
GRIND
PRESS OR FILTER
JUICE
PULP
FLASH DRY
SCREEN
PEEL
AIR CLASSIFY
FEED
STARCH
EVAPORATE
SPRAY DRY
PROTEIN MEAL

Figure 1. Initial Starch/Protein Meal Process Flow Chart

particles of pulp that were small enough to pass through the 200 mesh screen with the starch but were not removed by air classification - even when preceded by grinding at the most intensive setting on an Alpine American cross flow mill.

A critical review of the above results - especially in view of the ability of the traditional process to produce starch of extreme purity - led to a refinement that drastically improved starch quality, lowered wash water demand still further, and reduced capital equipment costs for the process.

MODIFIED STARCH PRODUCTION PROCESS

Figure 2 depicts the modified starch production process. Potatoes are ground as before and the slurry wet-sieved by flooding with recycled juice. The pulp remains above the 140-mesh screen while juice and starch pass through. The slurry is pumped to a liquid cyclone wherein the starch is spun to the underflow while the overflow is largely recycled to the screen. Excess juice at 4% total solids (w.b.) passes to the juice processing system.

The underflow starch is dewatered and washed on a belt vacuum filter (or some other device such as a basket centrifuge, decanting centrifuge, or rotary vacuum filter). In our trials to date, we have used a pilot (3 ft^2) horizontal belt filter produced by Straight Line Filter, Inc. The starch cake produced tested about 65% total solids (w.b.). The cake was dried in a tray drier at 140°F.

Liquid from the starch dewatering and washing step is recycled back to the liquid cyclone and is pumped into the tangential elutriation inlet. This particular design is a patented feature of the Bird Machine Co. This recycle stream is necessary to aid in removal of colloidal materials from the starch which otherwise interfere with the filtration step.

Rough tuning of this scheme to date using a wash stream of 25 pounds of water per 100 pounds of cull potatoes processed has produced starch of 0.3% protein (d.b.) and a reflectance reading of 87% even without air classification. Even better results should be achieved as additional experience is gained with the method and it is revised and tuned accordingly.

Upon air classification of the above starch, the reflectance increased to 89% while the protein level decreased to 0.16%. Small samples of this starch may be obtained on request.

PRELIMINARY ECONOMICS

Currently, cull potatoes are available at $0.75 per cwt. Each hundred weight should yield ten pounds of starch which, at 13¢ per pound, is worth $1.30. In addition, each hundred weight should yield four pounds of dried pulp, at $80.00 per ton, worth $0.16. Finally, a yield of 4 pounds of 50% protein meal, at $200. per ton, should be worth $0.40. Value of all

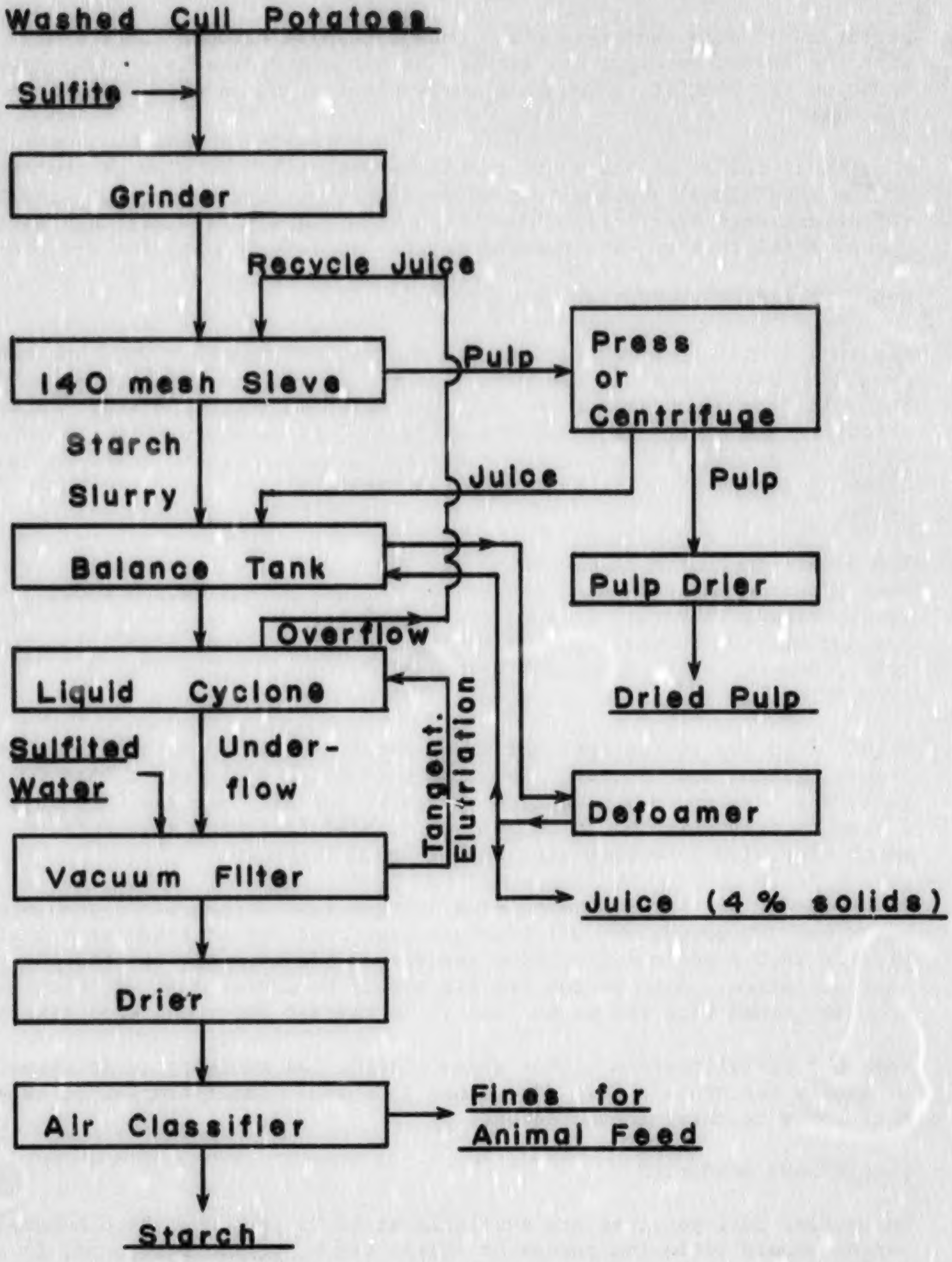
Washed Cull Potatoes
Sulfite
Grinder
Recycle Juice
140 mesh Sieve
Pulp
Press or Centrifuge
Starch Slurry
Juice
Pulp
Balance Tank
Pulp Drier
Overflow
Liquid Cyclone
Dried Pulp
Sulfited Water
Under-flow
Tangent. Elutriation
Defoamer
Vacuum Filter
Juice (4% solids)
Drier
Air Classifier
Fines for Animal Feed
Starch

Figure 2. Revised Starch Production Flow Chart

products is estimated at $1.86.

Energy costs for drying the starch and pulp and concentrating (with a four-effect evaporator) and drying the juice should be $0.13 (assuming $3.00 per million Btu). This leaves $0.98 per cwt. to cover profit, capital costs, and operational expenses. While it is premature to attempt to evaluate closely all economies of the process, communications with industry have indicated that these figures suggest a potentially profitable enterprise - especially since there are plants in existence that already have some of the appropriate equipment in hand.

It is interesting to note that test plots in the Connecticut River Valley have produced twenty ton of pototoes per acre. In the above terms, this corresponds to 4,000 pounds of starch ($520), 1,600 pounds of pulp ($64), and 1,600 pounds of 50% protein meal ($160). In comparison, soybeans produce about 700 pounds of protein per acre and alfalfa, about 2,400 pounds. Since most of the true protein (about 1/3 of the crude protein) of potato juice is heat coagulable, it has potential as an egg white substitute in some food systems. In addition, researchers at the University of Minnesota(10) have succeeded in breeding potatoes to twice their normal protein content.

JUICE PROCESSING

There are many possible processing schemes that could be applied to the 4% solids (w.b.) juice which contains about 50% crude protein (d.b.). Many of these schemes have been investigated particularly in the low concentration range by researchers at the Eastern Regional Research Center of the U.S. Department of Agriculture(6,9). The rapidly changing animal feed market (which includes the possibility of liquid feed concentrates), the relatively high solids concentration of the juice produced by the starch process described in this paper, and the rapidly changing state of the art of ultrafiltration and the reverse osmosis technology (11,12) suggests that continued work is appropriate.

Figures 3, 4, and 5 outline the three broad categories believed most promising, each of which carries a number of sub options to further maximize profitability: 1) the use of ultrafiltration to concentrate protein; 2) the use of heat and acid induced coagulation to concentrate or fractionate protein; and 3) concentration of juice without fractionation. The profitabilities of these options and sub options depend upon permeation rates within the ultrafiltration and reverse osmosis unit operations. These in turn depend on the previous processing history, concentration, flow rate, membrane type and configuration, system design, temperature, and membrane condition. The main thrust of the research planned for this coming year will focus on these flux rates so equipment and energy requirements of the various options may be more accurately determined for comparison with the more obvious methodology of vacuum evaporation followed by spray drying. A final goal of the project will be to design a complete plant and perform its detailed cost analysis. An additional goal is to review progress on a regular basis with industrial leaders so those portions of the work which

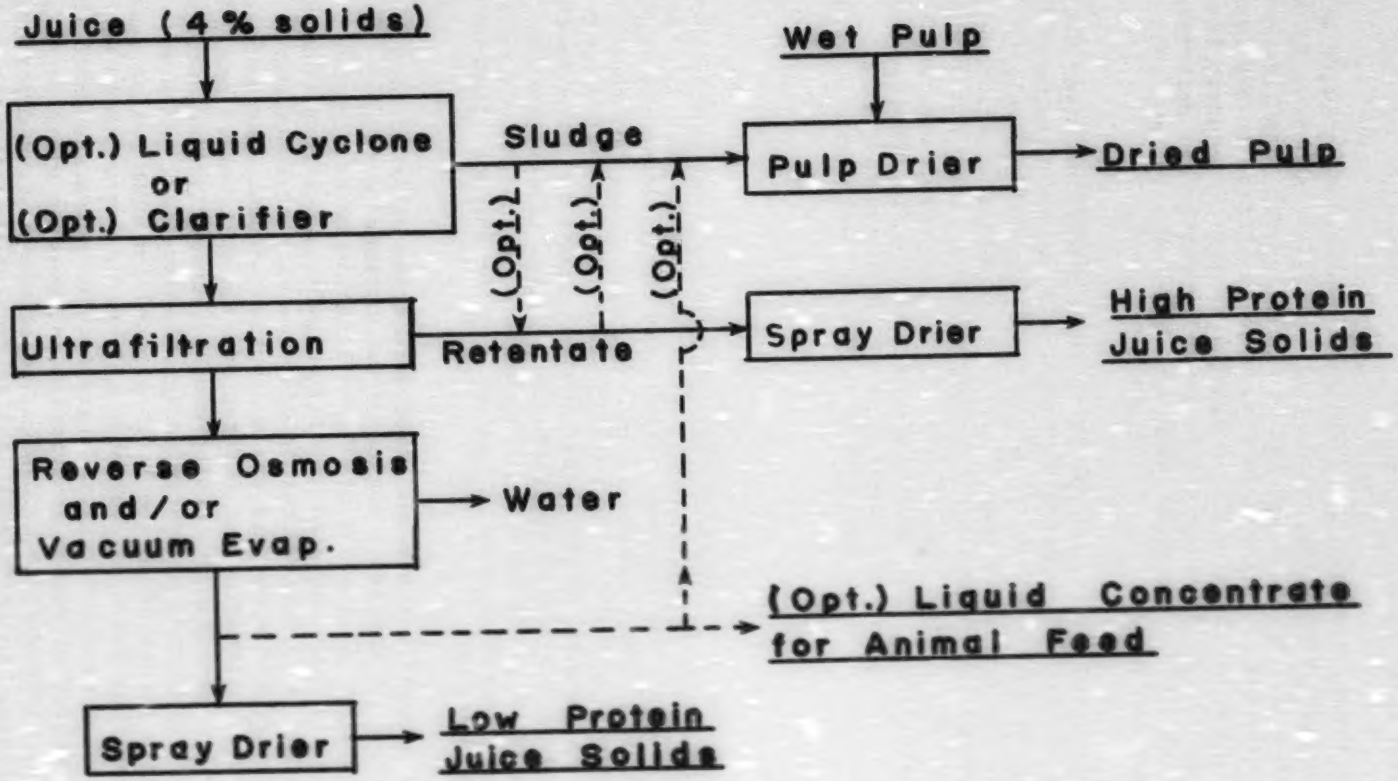
Juice (4 % solids)
(Opt.) Liquid Cyclone or (Opt.) Clarifier
Sludge
Wet Pulp
Pulp Drier
Dried Pulp
(Opt.)
(Opt.)
(Opt.)
Ultrafiltration
Retentate
Spray Drier
High Protein Juice Solids
Reverse Osmosis and/or Vacuum Evap.
Water
(Opt.) Liquid Concentrate for Animal Feed
Spray Drier
Low Protein Juice Solids

Figure 3. Juice Processing Flow Chart with Ultrafiltration

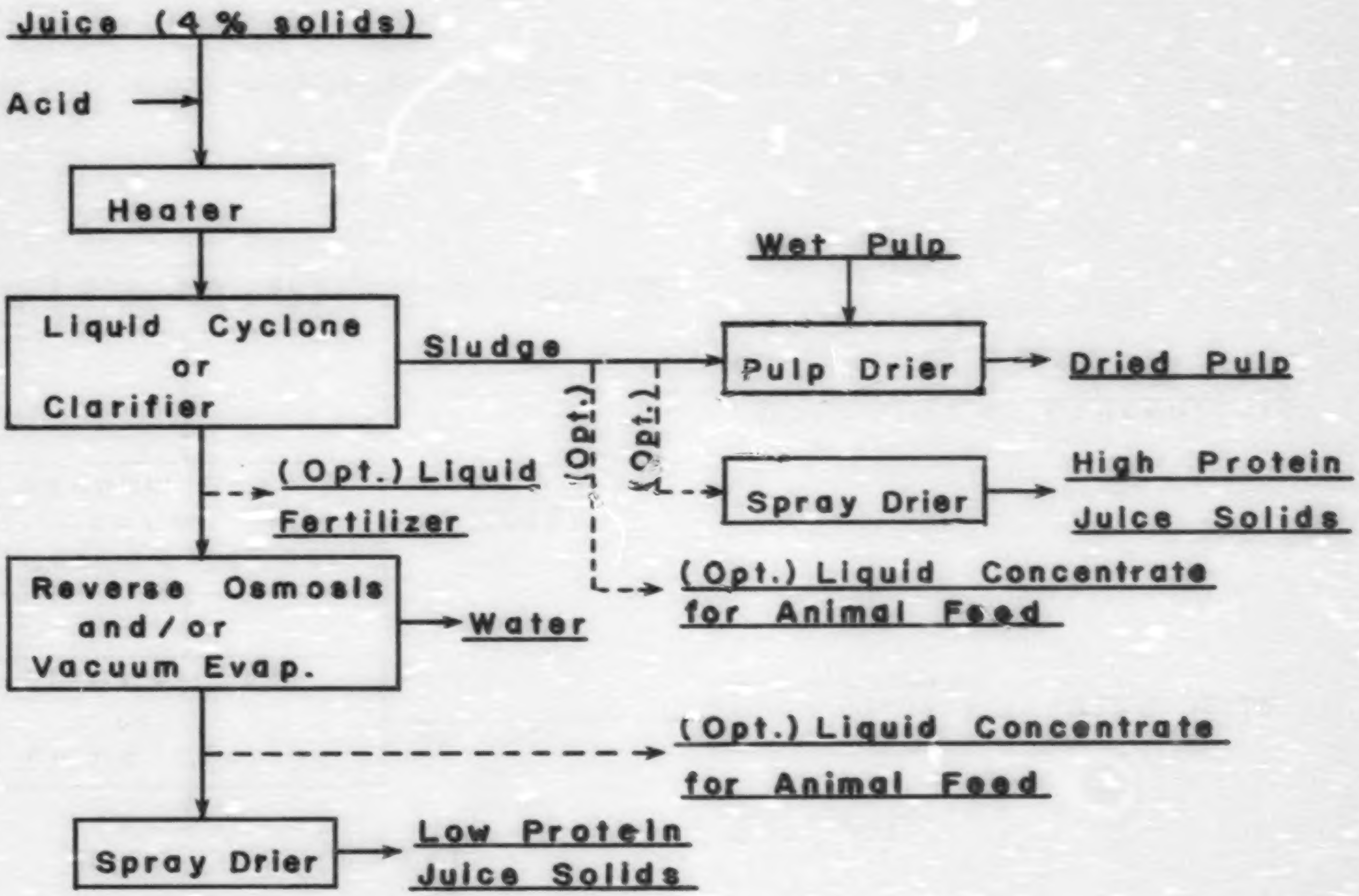
Juice (4 % solids)
Acid
Heater
Liquid Cyclone or Clarifier
Sludge
(Opt.)
(Opt.)
Wet Pulp
Pulp Drier
Dried Pulp
Spray Drier
High Protein Juice Solids
(Opt.) Liquid Concentrate for Animal Feed
(Opt.) Liquid Fertilizer
Reverse Osmosis and/or Vacuum Evap.
Water
(Opt.) Liquid Concentrate for Animal Feed
Spray Drier
Low Protein Juice Solids

Figure 4. Juice Processing Flow Chart with Heat Precipitation

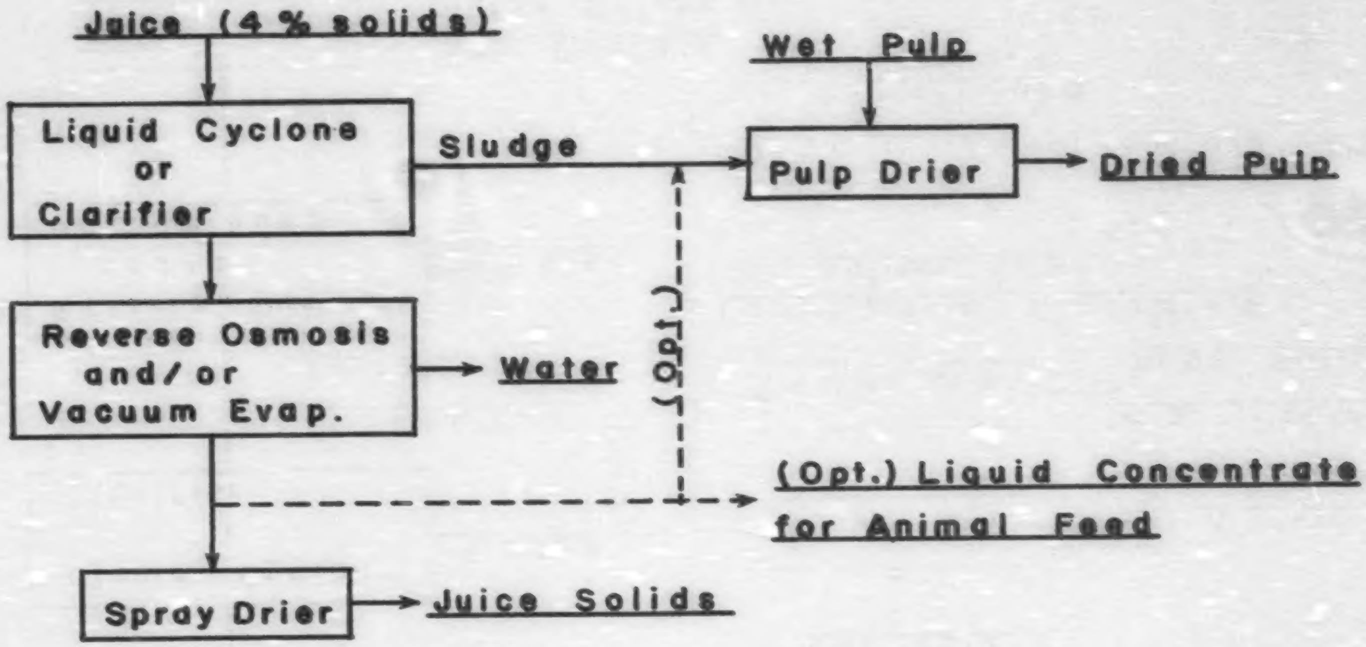
Juice (4 % solids)
Liquid Cyclone or Clarifier
Sludge
Wet Pulp
Pulp Drier
Dried Pulp
Reverse Osmosis and/or Vacuum Evap.
Water
(Opt.)
(Opt.) Liquid Concentrate for Animal Feed
Spray Drier
Juice Solids

Figure 5. Juice Processing Flowsheet without Protein Fractionation

have application to existing hardware can be implemented without delay.

FOAMING PROBLEMS

One of the properties of potato juice is that it foams readily. Samples of potato juice were transported to the Cornell Machine Co. plant in Springfield, NJ to evaluate their "Versator" defoaming machine. The juice was agitated to produce foam and processed in their eight and sixteen inch diameter machines which operate on the principle of sheeting a thin film of juice and foam together over a concave disk spinning in a vacuum chamber. The larger machine proved much more effective and has been ordered for addition to the pilot equipment as shown in Figure 2.

Recent tests on unfractionated juice have shown that foaming within the vacuum evaporator can be controlled with Down Corning FG-10 antifoamer used at 300 ppm.

SUMMARY

A low water process with no process water discharge has been developed for the production of starch, pulp, and protein meal from cull potatoes. The process currently produces starch of nearly equal quality to that produced by traditional methods. Ongoing research will continue to improve starch whiteness and characterize membrane flux rates in juice processing ultrafiltration and reverse osmosis operations. Results of this work will lead to a complete plant design and cost analysis.

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CHANGES IN ORGANIC AND INORGANIC CONSTITUENTS OF WASH WATER UPON RECYCLE IN A PROTOTYPE LEAFY-GREENS WASHER*

by

R. C. Hoehn,** P. B. Geering,** M. E. Wright,*** and W. H. Robinson, Jr.***

INTRODUCTION

Food-processing industries reportedly are one of the major consumers of fresh water in the United States, using about 99 billion gallons annually.(1) Fresh water not only is costly but also the supply sometimes becomes inadequate, most often when wells are the source, and especially in rural locations where industries provide their own water. Restrictions on industrial discharges under the provisions of the National Water Quality Act Amendments of 1972 (Public Law 92-500), coupled with increasing costs of obtaining fresh water, have caused most industries to study their operations and find ways to minimize water consumption.

Industries that process leafy vegetables use large volumes of water, mainly during four operations: 1) washing; 2) blanching; 3) cooling, and 4) transporting product. Three types of washers are most commonly used in commercial operations: immersion, spray-belt, and rotary-spray. Estimates of wash-water requirements per unit weight of product range from 50 per cent of a total 3 to 5 gallons per pound (gal/lb) [25.0 to 41.6 liters per kilogram (ℓ/kg)] necessary for complete processing (2) to 73 per cent of a total 1.1 to 1.5 gal/lb (9.1-12.5 ℓ/kg) cited by Bough.(3)

One obvious way to conserve water in a greens-washing operation is to modify the system in some manner to permit recycling of the wash water itself. Of course, the chief concern is that the recycled water be of

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** Respectively, Associate Professor and Graduate Research Assistant, Civil Engineering Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

*** Respectively, Associate Professor and Graduate Research Assistant, Agricultural Engineering Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

sufficiently good quality throughout the period of use to insure that the product quality will not be degraded beyond acceptable limits. However, relatively little is known about the effects of recycling on product quality, though water conservation is practiced in other ways in processing operations, so in 1973 a proposal was made to the Environmental Protection Agency that a project be funded to design and evaluate a full-scale, immersion-type washer that would permit the recycling of wash water during greens-washing operations. The proposed system was to be a further modification of one constructed earlier that had been shown to be more effective than conventional systems for removing insects and trash from leafy greens.(4) The proposed project was approved to begin in May, 1974, and the washer was tested during the period from October through December, 1975.

The objective of this paper is to describe the modified system and to present a summary of data showing its performance during five trials, four when collard greens were being processed and one when spinach was being processed. The evaluation was conducted at Exmore Foods, Incorporated, a frozen-food company on the Eastern Shore of Virginia. Detailed information concerning water and product quality, water usage rates, and wastes generated per ton of vegetable processed during the five trials will be presented.

THE WASHING SYSTEM

A diagram showing water- and product-flow routes is presented in Figure 1. The two washers, designed to wash 4,000 lb (1773 kg) of product per hour (hr), were each 4 feet (ft) [1.22 meters (m)] wide and 16 ft (4.88 m) long. The bottoms were comprised of three sections, each V-shaped to facilitate the collection and removal of grit when the washers were drained. The maximum depth in each tank was 3 ft (0.92 m), and the nominal capacity of each was 688 gal [2.60 cubic meters (m^3)]. Water in each washer was recycled through a separate settling tank 8 ft (2.44 m) long by 4 ft (1.22 m) wide, with a maximum depth of 4 ft (1.22 m) and a nominal capacity of 718 gal (2.71 m^3).

Both washers were identical and were operated in series. Each was equipped at the input end with three banks of sprayers (4 nozzles each), one bank placed at water level and two above the incoming product. One of the overhead banks of sprayers was later taken out of service in order to maintain high pressure on the nozzles while reducing the overall recirculation rate from 200 gpm(757 ℓ/min) to approximately 125 gpm (473 ℓ/min). This was necessary because it was discovered that the washer drain system and the return sump pump (described later) could not handle the larger flow.

As product entered, it was spread and vigorously agitated by the sprayers and was pushed toward the first of three,center-mounted, paddle wheels covered with flattened, expanded metal. The three, revolving paddle-wheel drums propelled the product through the washer, alternately submerging and releasing it. Insects and leaf fragments floated to the surface inside each drum while product was submerged, and water, forcefully dispensed through a stationary bank of three spray nozzles (positioned inside each drum) prevented leaves from becoming entangled in the expanded-

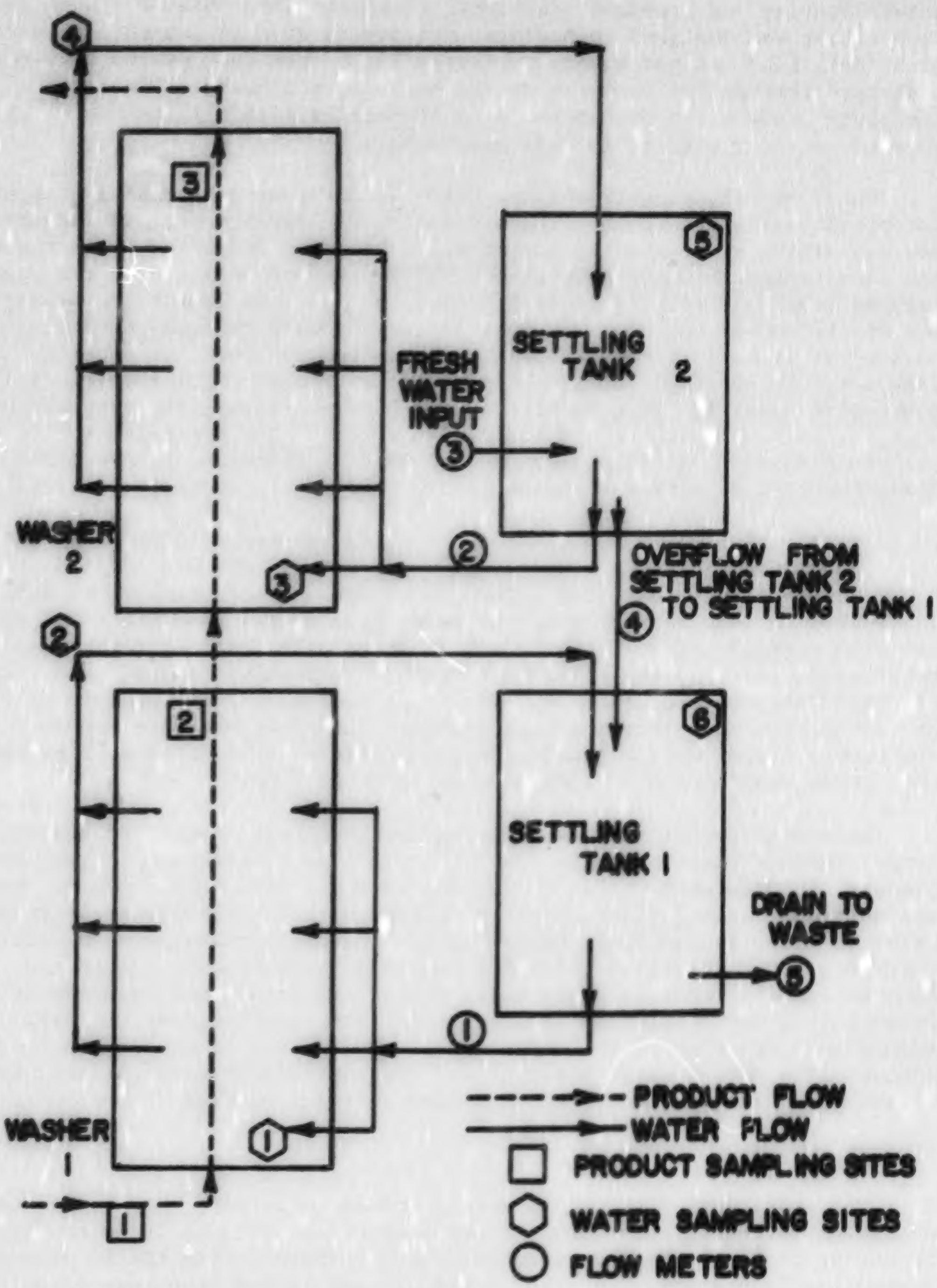
4
3
5
SETTLING TANK 2
FRESH WATER INPUT
3
WASHER 2
2
3
OVERFLOW FROM SETTLING TANK 2 TO SETTLING TANK 1
4
2
2
6
SETTLING TANK 1
DRAIN TO WASTE
5
1
WASHER 1
1
1
PRODUCT FLOW
WATER FLOW
PRODUCT SAMPLING SITES
WATER SAMPLING SITES
FLOW METERS

Figure 1. Diagram of experimental recirculating washer system.

metal covering and provided additional cleaning. The sprayer system in each washer was designed to operate at a pressure of 35 pounds per square inch (psi) [2.5 kg per square cm (kg/cm^2)], 57 per cent of the flow being dispensed through the sprayers at the head of each washer. An exit conveyor-- made of an open-mesh, plastic belting with flights every 2 ft (0.6 m)—carried product out of each washer.

Water and floating trash that collected inside the rotating drums flowed out of the washers through surface side-drains into a trough leading to a box containing a submersible sump-pump. This pump forced water into the settling tanks through a moving-belt filter made of polyester screen that trapped trash and carried it to a collection box. Streams of compressed air at the end of the conveyor were directed upward through the belt across its width to force trash into the collection box. Each settling tank was 8 ft (2.44 m) long, 4 ft (1.22 m) wide and a maximum of 4 ft (1.22 m) deep and was baffled to prevent floating debris from getting into the pump that forced water back to its respective washer. The nominal capacity of each tank was 688 gal ($2.60\ m^3$) and provided a detention of approximately 7 min for grit to settle when the recirculation rate was 100 gpm (378.5 ℓpm).

Fresh, chlorinated water was added to the system at only one point: the second settling tank. The overflow was carried through an HS-flume into the first settling tank. The volume in excess of that required to make up for losses in each washer, caused by carry-over on the product, was discharged as waste from the first settling tank through a second HS-flume. Flow meters were installed to permit monitoring of fresh-water input and recirculation rates, which could be controlled by opening or closing gate valves, through each washer-settling tank system. The HS-flumes were equipped with continuous stage-recorders and were calibrated so that depth of flow through the flumes could be converted to volume rate of flow.

An overhead photograph of the system, along with the field trailer and rotary tumbler used to remove some of the grit and insects from the unwashed product, is presented in Figure 2. Not shown are the components of the conventional washing system that interfaced with the experimental system. Prior to entering the first washer of the prototype system, dry product was carried by conveyor belts through inspection lines where yellowed and damaged leaves, weeds, and any other foreign materials were removed by hand. Product feed rates into the washing system varied throughout the day, mainly as a function of the condition of raw product as it came in from the fields. The more foreign material and unacceptable product present, the slower the feed rate had to be to insure thorough sorting.

METHODS

The prototype of the experimental system interfaced with the commercial operation so that greens from the dry inspection belts could be conveyed to either the experimental or conventional washers. When the experimental system was in operation, greens passed through it and then were rewashed and further processed by the conventional system. Because the two systems were interfaced, the experimental operation was subjected to the same variables one would encounter in a commercial operation (delays due to

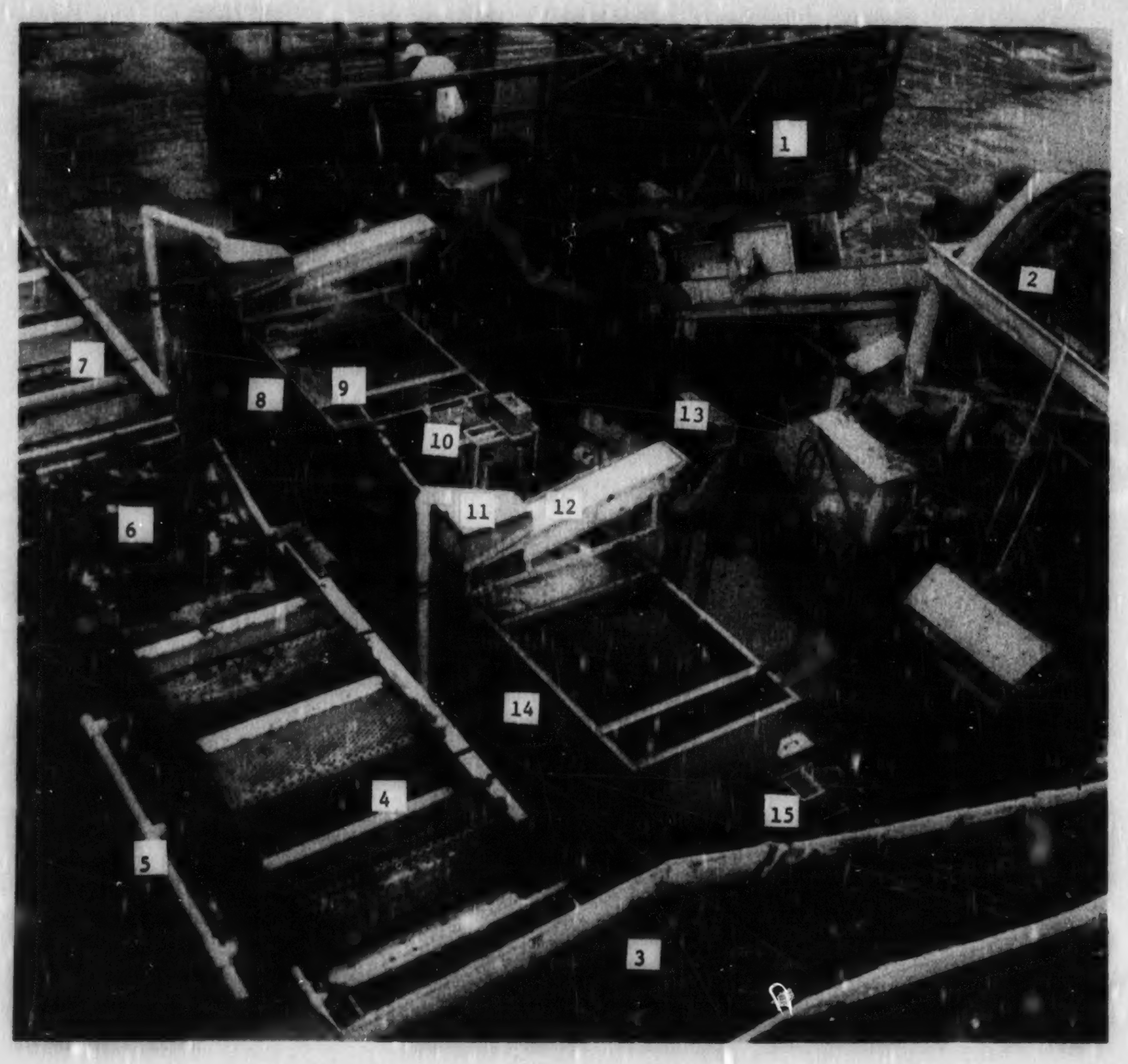

Figure 2. Components of experimental washing system: 1. Field trailer. 2. Rotary tumbler. 3. Conveyor from tumbler to dry inspection belts. 4. Washer No.1. 5. Side-drain trough to sump. 6. Conveyor for product from Washer No. 1. 7. Washer No. 2. 8. Settling tank No. 2. 9. Fresh-water influent. 10. HS-Flume for monitoring flow between settling tanks. 11. Discharge of sump pumps from Washer No. 1. 12. Conveyor belt filter for removing larger particulates. 13. Trash collector. 14. Settling tank No. 1. 15. HS-Flume for monitoring waste discharge from Settling tank No. 1.

equipment failure, work breaks, etc.). One disadvantage was that the type greens available at the times chosen to operate the experimental system was dependent upon harvesting schedules, and, because schedules could not be rigidly followed, the original plan of washing a variety of greens in the experimental system was not possible. However, replicate washings of one type green did serve to demonstrate the variations one might encounter in the quality of both wash water and final product resulting from differences in several cuttings of the same green.

Description of a Typical Trial

Immediately before processing was to begin, the operation of the experimental system was checked, and water-flow rates were adjusted and recorded. The time when product feed to the system actually began was recorded, and soon thereafter, usually 15 min later, samples of water and product were collected for analysis at sites shown in Figure 1. Samples then were collected at hourly intervals throughout the entire period of actual plant operation. Many tests of water quality were performed on site between sampling periods, but samples to be used for some analyses were preserved and returned to the university laboratory.

The total number of packages of processed product were recorded hourly, and periodically meters were read to determine recirculation rates and fresh-water input rates. At the end of the trial, trash collected from the washing system was collected and weighed, the tanks were drained, and the grit was collected. Samples of grit, trash, and frozen product were returned to the university laboratory for analysis.

Water and Product Analyses

Water quality analyses included biochemical- and chemical oxygen demand (BOD and COD, respectively), total chlorine residual, total and volatile suspended solids, and total bacterial population densities as determined by plate counts. Standard Methods for the Examination of Water and Wastewater(5) was followed for determinations of BOD, COD, chlorine residual (by the amperometric method), solids, and total plate count.

A portion of each product sample was frozen for later analyses of residual insects and bacteria present on the greens. Insect counts were determined by a gasoline-flotation test used routinely at Exmore Foods, Inc. and described by Frey(6). Product bacterial densities were determined also by methods used at Exmore Foods, Inc., namely by plating aliquots of serial dilutions (on Total Plate Count Agar) made after vigorously shaking 11 grams (g) of product in 90 milliliters (ml) of sterile. buffered, dilution water and counting the colonies that developed after 24-48 hr incubation.

Another product portion was weighed immediately after collection, blotted with paper towels to remove excess water, and reweighed. The samples then were frozen and later were dried at 105 degrees Celsius (^{o}C) for 24 hr and reweighed. The moisture content of each sample was calculated from the relationship:

$$M = \frac{100\ W_w}{W_w + W_d}$$

where: M = moisture content on a wet basis

W_w = weight of water

W_d = weight of dry matter.

Moisture contents of the packaged product also were determined, and reasonable estimates of the total weight of product processed per hour could be calculated by multiplying the total package weight by a fraction obtained by dividing the moisture contents of raw and finished products. Product feed rates through the washing system could be determined, and the observed changes in product- and water quality could be related to the total, fresh weight of product. This method of expressing data permitted more valid comparisons from trial-to-trial than if product- and water quality changes had been expressed as functions of time because, as has been mentioned previously, product feed rates varied considerably.

Grit Analysis

Grit-- including sand, silt, and clay-- was collected at the end of each trial, dried at 105°C for 24 hr, and weighed. A particle-size analysis then was performed: the standard hydrometer method(7) was used for particles smaller than 50 nanometers (nm) and a sieve analysis(8) was used for larger particles.

RESULTS AND DISCUSSION

Operational and waste-characterization data describing the washing system and wash-water quality, respectively, will be presented in this section, along with representative data to illustrate the following:

1) the effectiveness of the first washer-settling tank subsystem in the total washing operation,
2) the effects of different cuttings of collards in altering wash-water quality,
3) the variations in water quality caused by the action of a washer and settling basin,
4) the relative variations in wash water quality observed when spinach and collards were processed, and
5) product quality as reflected by bacterial densities and insect counts.

In addition, the wastes generated per unit weight of fresh product processed will be presented and compared to data presented by Bough.(3)

Operational Data

Table 1 shows specific details of the five evaluations of the experimental washing system. The water usage by the experimental system, expressed as volume per unit product weight, was from 2 to 3 times less than that estimated by Bough(3) for a commercial cannery and from 3 to 5 times less than an estimate given by Whittington et al.(2), the latter being for the Exmore Foods operation.

TABLE 1. PERFORMANCE DATA FOR THE PROTOTYPE WASHING SYSTEM DURING FIVE TRIALS

		Processed Product Weight*		Average Product Feed Rate		Water Use per Unit Product		Flow Rate of Makeup Water	
Trial	Processing Time,hr.	Tons	10^3 kg	Tons/hr	10^3 kg/hr	gal/lb	ℓ/kg	gal/min	ℓ/min
#1**	4.0	4.9	4.4	1.2	1.1	0.62	5.16	12.7	48.1
#2	5.8	11.0	10.0	1.9	1.7	0.42	3.50	18.3	69.3
#3	6.8	9.5	8.6	1.4	1.3	0.48	3.99	15.2	57.5
#4	6.8	8.7	7.9	1.3	1.2	0.55	4.58	16.6	62.8
#5	4.2	4.4	4.0	1.0	0.9	0.75	6.25	15.2	57.5

(Trials #1-4: Collards; #5: Spinach)

* Fresh weight

** Estimated data involving product weight based on the average, fresh weight of other collard cuttings washed during the project

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It should be pointed out, however, that the flow data in Table 1 are measured values, not estimated, and the quantity of water conserved when operating the prototype actually is more apparent when the volume rates of flow are compared. The two conventional washers at Exmore Foods are operated at flow rates of 35 gal/min (132.5 ℓ/min) each for a total of 70 gal/min (265 ℓ/min). Bough(3) estimated 74-84 gal/min (280-318 ℓ/min) and 180-200 gal/min (681-757 ℓ/min) used in dunker washers and reel washers, respectively, at a commercial cannery. The prototype recirculating system, on the other hand, was operated at an average rate of only 15.6 gal/min (59 ℓ/min), a considerable savings indeed (77 per cent less than at Exmore Foods).

Chemical Characterization of Waste Water

Table 2 presents selected chemical characteristics of waste water in settling tank No. 1 at the end of a processing day. The low and high concentrations were observed, respectively, on the days when the least and greatest mass of collards were processed. Note the relative magnitude of total suspended solids (TSS) concentrations present when spinach and collards were processed. The much higher concentration obtained by washing spinach reflects the difference in leaf shapes of the two greens, spinach having a convoluted surface that can hold more dirt than the relatively smooth-surfaced collard greens. Figure 3 clearly illustrates the differences.

TABLE 2. CHEMICAL CHARACTERISTICS OF WASH WATER WASTED FROM SETTLING TANK NO. 1 AT THE END OF THE PROCESSING DAY

Waste Component, mg/ℓ	Collards			Spinach
	Average	Low	High	
TSS	171	109	220	689
VSS	110	61	155	57
COD	356	262	439	211
BOD_5	80	66	97	46
Processed Fresh Weight				
Tons	8.5	4.8	11.0	4.4
10^3 kg	7.7	4.4	10.0	4.0

Concentrations of three of the four chemical characteristics in Table 2 reported by Bough(3) in a study at a commercial cannery are presented in Table 3. In general, the concentrations of the various waste components were much greater at the cannery where Bough's work was conducted. The reason is not clear, and the differences are surprising because the experimental washing system in this study was a recirculating type, which permits waste components to accumulate and become highly concentrated.

The differences in Bough's data and that derived from this study are just as great when compared on the basis of the product weight processed. Table 4 shows a comparison of the waste loads per ton calculated from data collected during the two studies.

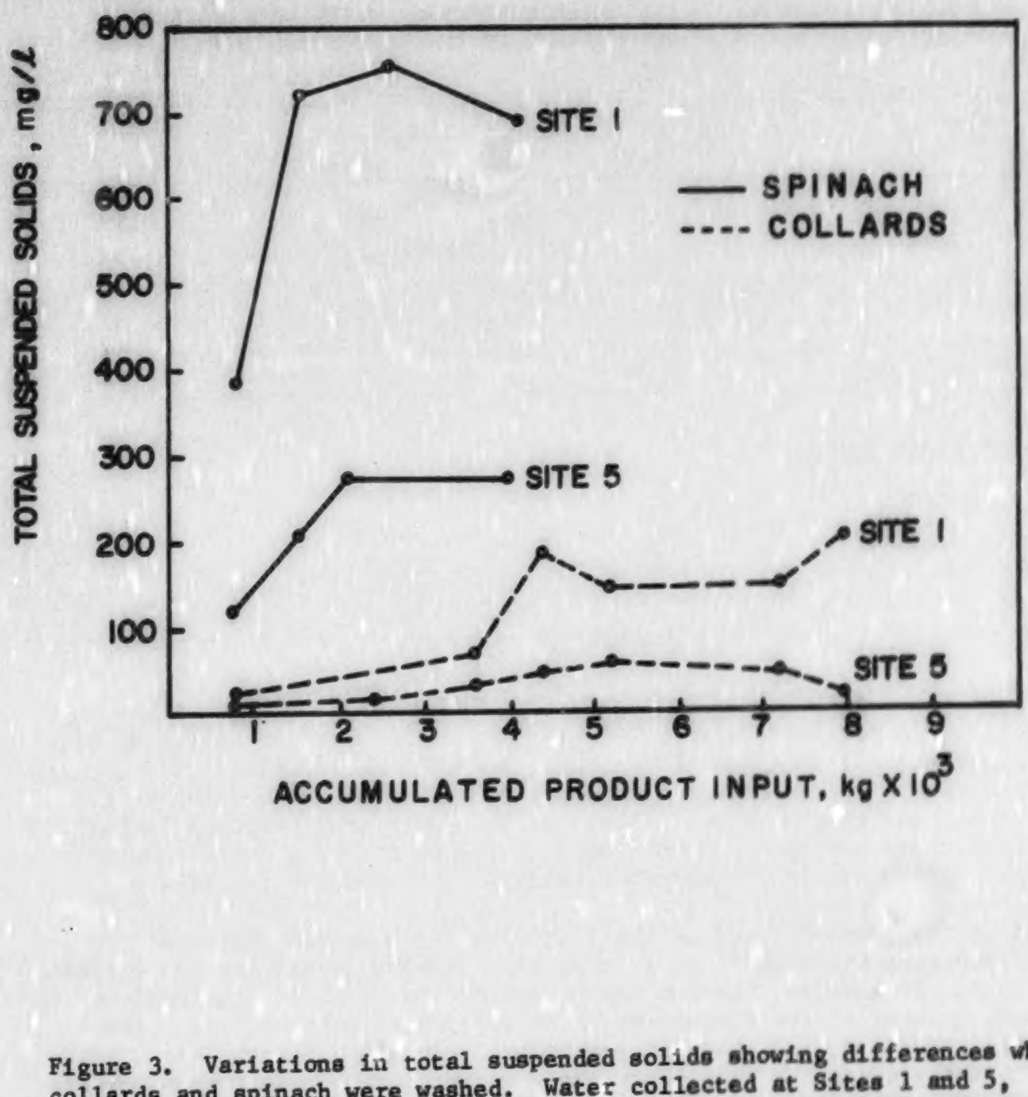

Figure 3. Variations in total suspended solids showing differences when collards and spinach were washed. Water collected at Sites 1 and 5, respectively, were settled water from the first settling tank entering washer No. 1 and unsettled water entering the second settling tank from washer No. 2.

TABLE 3. CHARACTERISTICS OF WASTE EFFLUENTS FROM THE WASHING OF COLLARDS AND SPINACH AT A COMMERCIAL CANNERY REPORTED BY BOUGH(3)

Waste Component	Waste Concentration, mg/ℓ			
	Collards		Spinach	
	Mean	s*	Mean	s*
TSS				
Dunker Washer	261	116	973	578
Reel Washer	62	22	159	28
COD				
Dunker Washer	633	268	1322	366
Reel Washer	325	125	528	155
BOD_5				
Dunker Washer	223	115	263	37
Reel Washer	122	51	185	64

* Standard deviation

TABLE 4. A COMPARISON OF WASTE LOADS GENERATED IN THE PROTOTYPE WASHING SYSTEM WITH THOSE CALCULATED BY BOUGH (1973) IN A COMMERCIAL CANNERY. DATA GIVEN ARE POUNDS WASTE PER TON OF FRESH PRODUCT*

Component	Collards, lb/ton		Spinach, lb/ton	
	This Study**	Bough's Value+	This Study	Bough's Value+
TSS	0.72	1.79	4.89	5.63
VSS	0.43	-	0.42	-
COD	1.72	9.37	1.81	12.37
BOD_5	0.42	2.51	0.35	3.41

* or kg per 2×10^3 kg of product

** Average of three trials

+ Dunker Washers plus Reel Washers

The waste loads in this study were the sums of three components: 1) waste in wash water carried out of the system on the product, 2) waste discharged continuously from the first settling tank, and 3) waste remaining in the washers and settling tanks at the end of the processing day.

If, in fact, Bough's(3) estimates of water usage were reasonably accurate (he stated that they were based on intermittent estimates of flow), the best explanation for the observed differences in wash-water characteristics and waste loads (Tables 3 and 4) is that there were vast differences in the cuttings of greens processed during the two studies. Differences in organic constituents and loads (COD and BOD_5) could be explained if the commercial washers damaged the product more than the prototype recirculating system, but there is no evidence that such damage actually occurred. More data of the type presented in Tables 3 and 4 will have to be collected before the observed differences between Bough's results and those of this study can be explained.

One additional comparison among data in Table 4 should be made; namely, that for waste loads of spinach with those of collards. Note that the total loads for three of the four waste water components (VSS, COD, and BOD_5) per ton of product processed, were similar in magnitude regardless of whether spinach or collards were being processed. As was discussed previously, however, the suspended solids load contributed by spinach was much greater than that contributed by collards.

Relative Effectiveness of the Two Washer-Settling Tank Subsystems

Figures 4 and 5 illustrate what was observed in every trial, namely that water in the first washer-settling tank subsystem became progressively "dirtier" than that in the second subsystem as more and more product was processed. There are two reasons. First, most of the cleaning actually did occur in the first subsystem; second, fresh make-up water was added to settling tank No. 2, providing a continuous dilution of the wash water in the second subsystem. A mass accounting within the total system, based on concentrations in the units at the end of a processing day, showed that an average 71 per cent of the suspended solids and organic matter was contained in the first washer and settling tank. Figures 4 and 5 clearly reflect this fact and, in addition, illustrate that the rate of increase in waste water constituents was much greater in the first subsystem. Note also that the water quality changes are expressed as functions of accumulated product input rather than operating time, because feed rates in the several trials varied considerably making invalid any comparisons based on time. Figure 6, showing the product-feed rate for one trial, is typical of the observed variations in other trials.

Variations in Water Quality with Different Cuttings of Product

In retrospect, it was fortunate that 80 per cent of the effort in this project was with one type green, because the data showed that wash-water quality can vary considerably even when the same product is being processed. Bough(3) also observed considerable variation, as is evidenced by the high

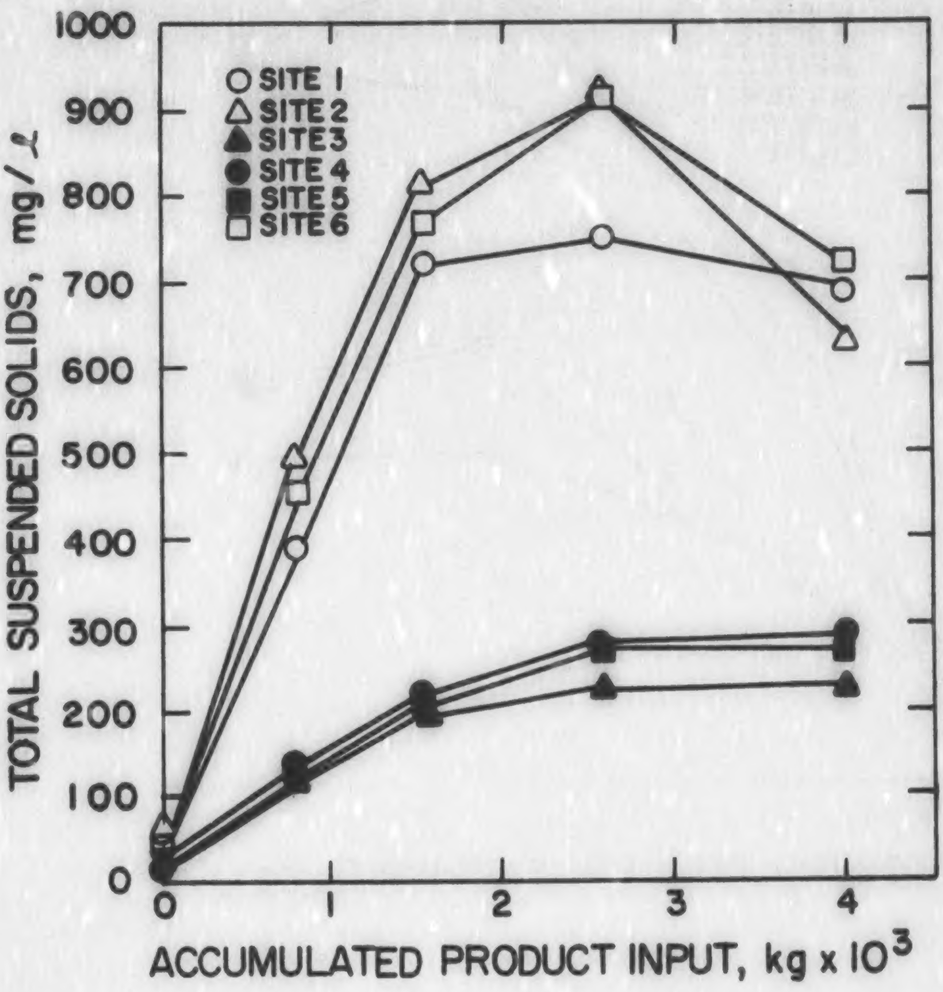

Figure 4. Variations in total suspended solids concentrations of water from all six sampling sites during the washing of spinach. Sites 1, 2, and 6 were within the first washer-settling tank subsystem. Sites 3, 4, and 5 were within the other subsystem.

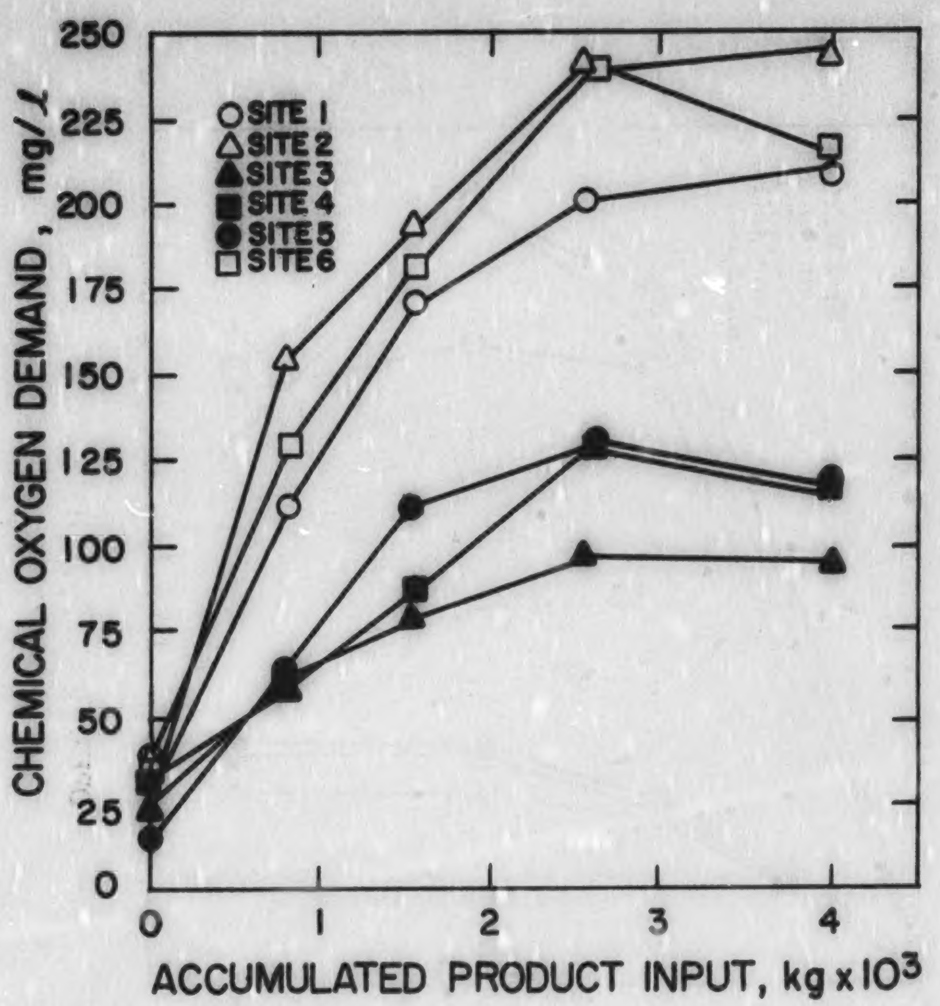

Figure 5. Variations in chemical oxygen demand concentration of water from all six sampling sites during the washing of spinach. Sites 1, 2, and 6 were within the first washer-settling tank subsystem. Sites 3, 4, and 5 were within the other subsystem.

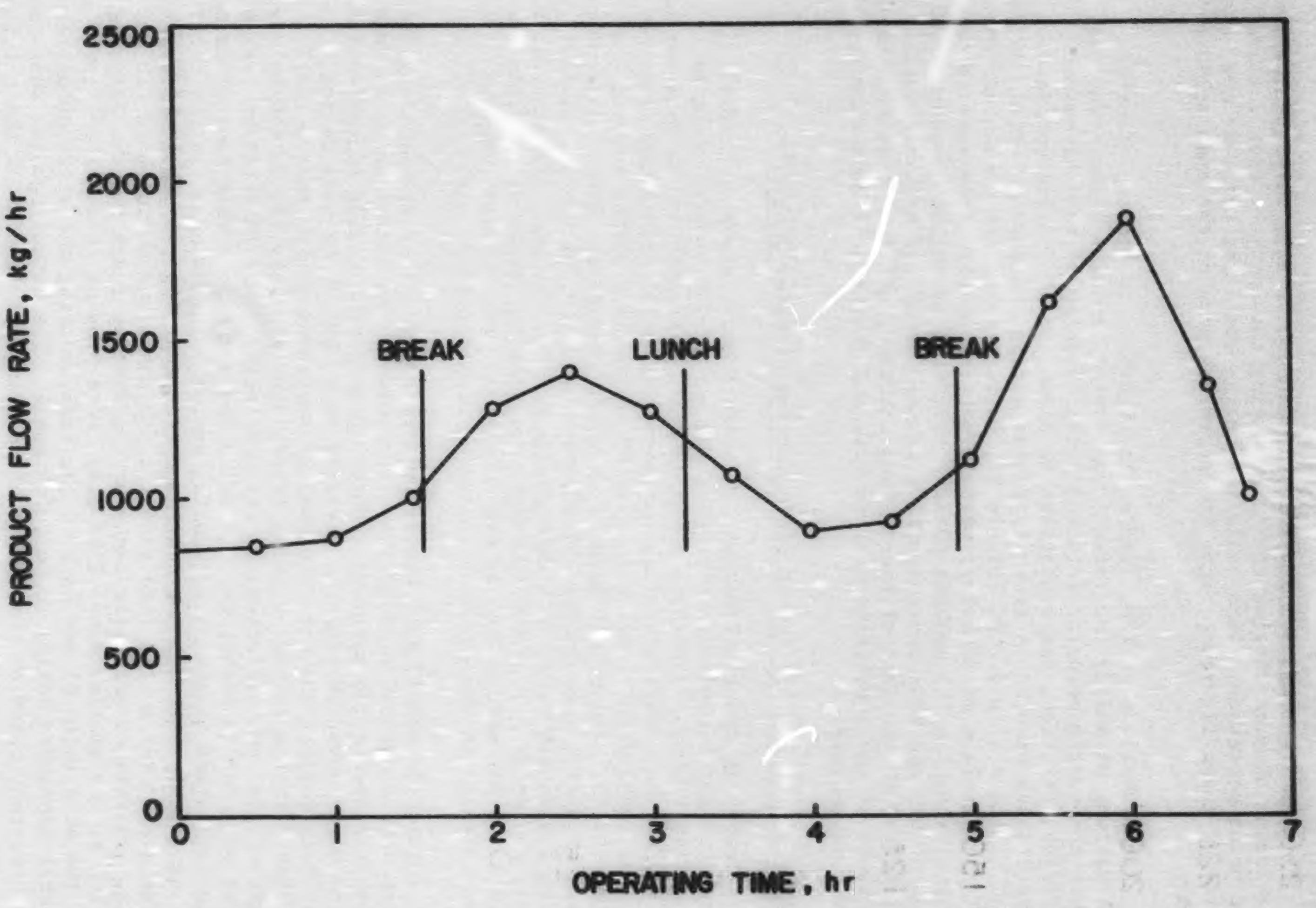

Figure 6. Variations in product flow rates during a typical processing day.

standard deviations of the mean concentrations he reported (See Table 3).

Figures 7 through 9 illustrate differences in only three of the many waste water characteristics monitored during this project when collards were being processed. Data collected during the first trial do not appear on any of these figures because no record was made of the cumulative product input.

The reductions in TSS, evident in Figure 7, is typical of other observations of solids and reflect the overall results of interactions within the system between different settling rates of variable-sized particles, dilution, and variations in cleanliness of different loads of vegetables brought in from the fields during the day. Chemical oxygen demand (Figure 8) and BOD_5 (Figure 9), indicative of the concentrations of small particulate or dissolved organic matter, usually increased continuously throughout the washing period. Differences in the absolute magnitudes of COD and BOD_5 concentrations were observed and probably reflect differences in the ages of the various cuttings, a factor that affects the thickness of the protective leaf cuticle and the general tenderness of the leaves themselves.

Effects of Washing Action and Sedimentation of Water Quality

Figures 10 and 11 illustrate the effects that vigorous product agitation had on water quality. The changes in COD brought about by propelling the greens through the washer are reflected by the area between the two curves. Water entering the washer (site 1) originated from the settling tank; water leaving the washer at the side drains entered the sump (site 2). Hence, differences in water quality at those two locations represent differences induced by vigorous agitation within the washer. During the fourth trial with collards and during the only spinach-washing trial, the increases of COD caused by the washing action were on the order of 10 to 20 per cent. The highest increases, about 40 per cent, were observed early in the day when the water was relatively clean.

Figures 12 and 13 show the effectiveness of one of the settling tanks in removing suspended solids. The area between the curves shown in each figure represents the apparent changes in suspended solids concentrations as the water moved through the settling tank, but these data do not accurately reflect the total removal of suspended solids that actually occurred. In the spinach-washing trial, approximately 132 lb (60 kg) dry weight of grit was collected, 63 per cent being found in settling tank No. 1 and 12 per cent in washer No. 1, indicating once again that most cleaning of product occurred in the first washing system. The material in the settling tank was mostly silt (55 per cent) and fine sand (34 per cent) while that in the washer was mostly fine sand (70 per cent) and medium sand (20 per cent). Therefore, while the tanks were effective traps for the larger grit particles, the smaller ones, like clay, were present in water collected at both the head (site 6) and back of the tank, causing the apparent difference in total suspended solids to be quite small. The actual removal that must have occurred, based on the weight of sediment collected from the settling

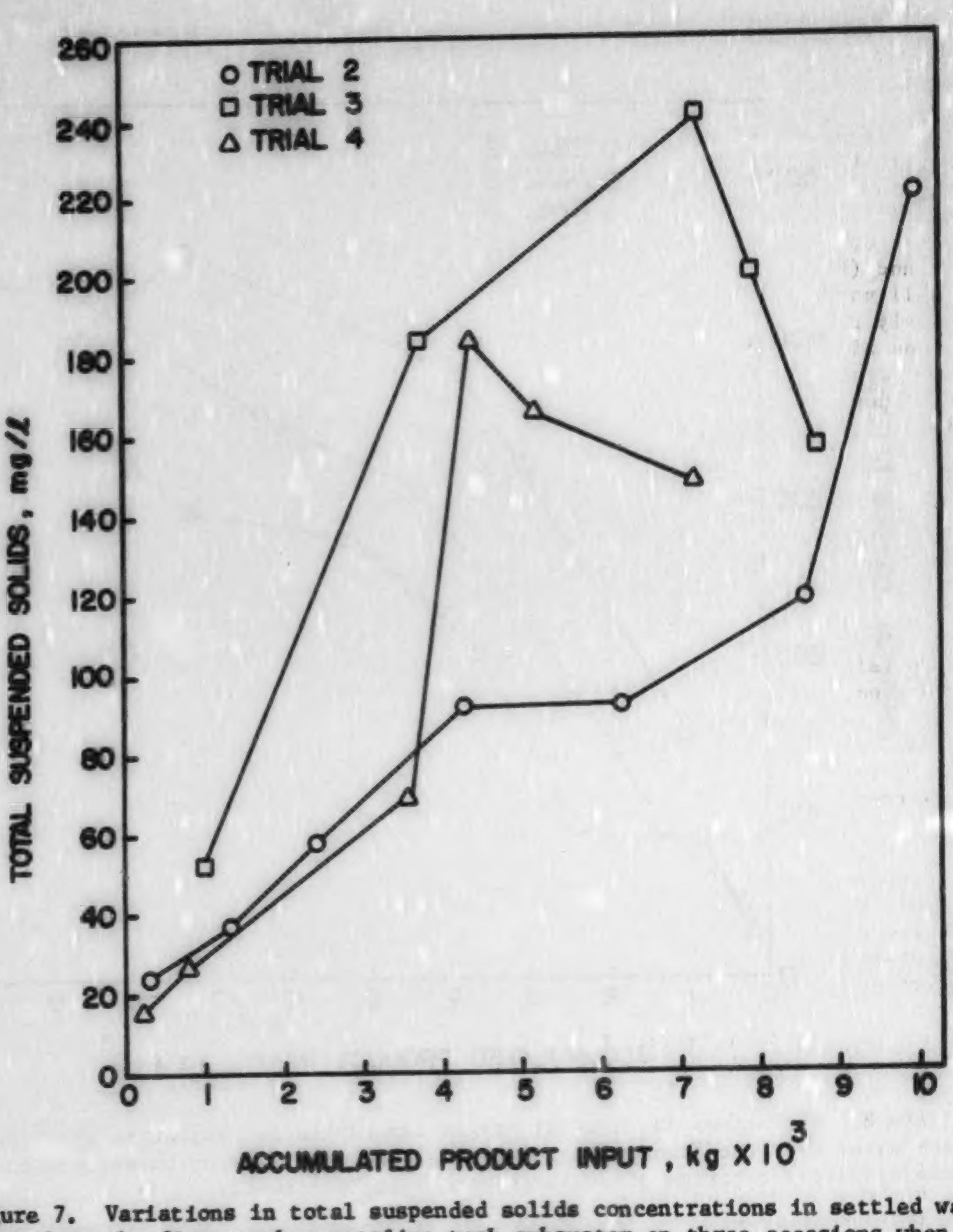

Figure 7. Variations in total suspended solids concentrations in settled wash water from the first washer-settling tank subsystem on three occasions when different cuttings of collards were being processed.

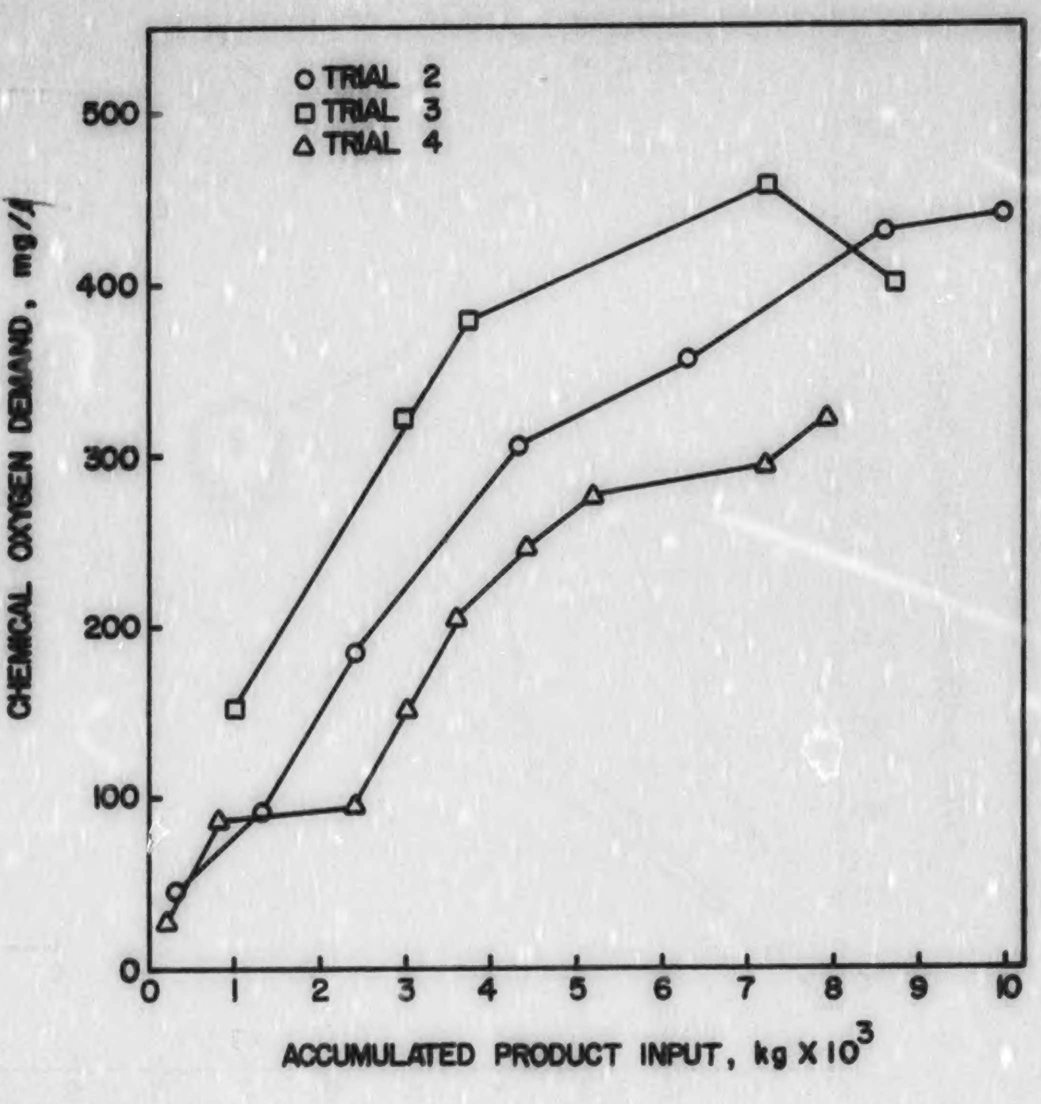

Figure 8. Variations in chemical oxygen demand concentrations in settled wash water from the first washer-settling tank subsystem on three occasions when different cuttings of collards were being processed.

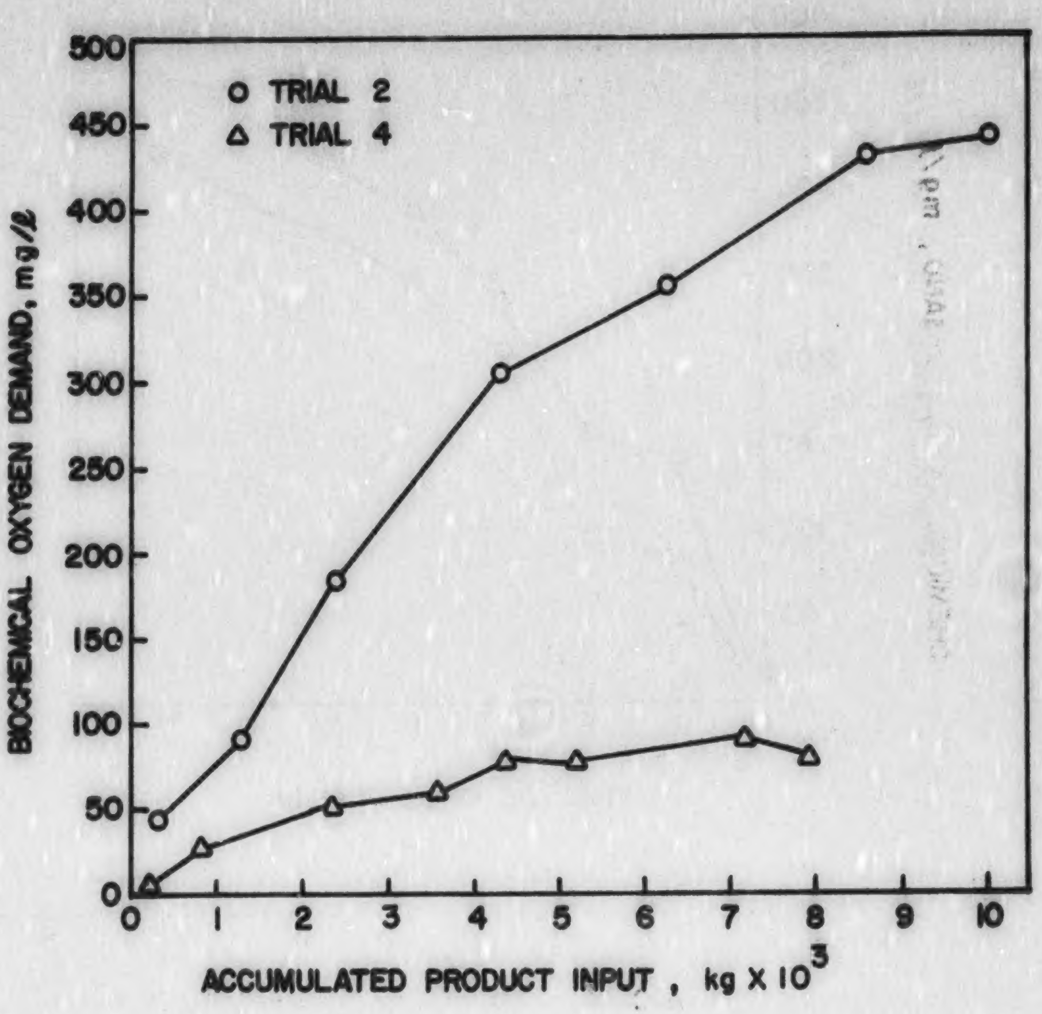

Figure 9. Variations in the five-day biochemical oxygen demand of settled wash water from the first washer-settling tank subsystem on two occasions when different cuttings of collards were being processed.

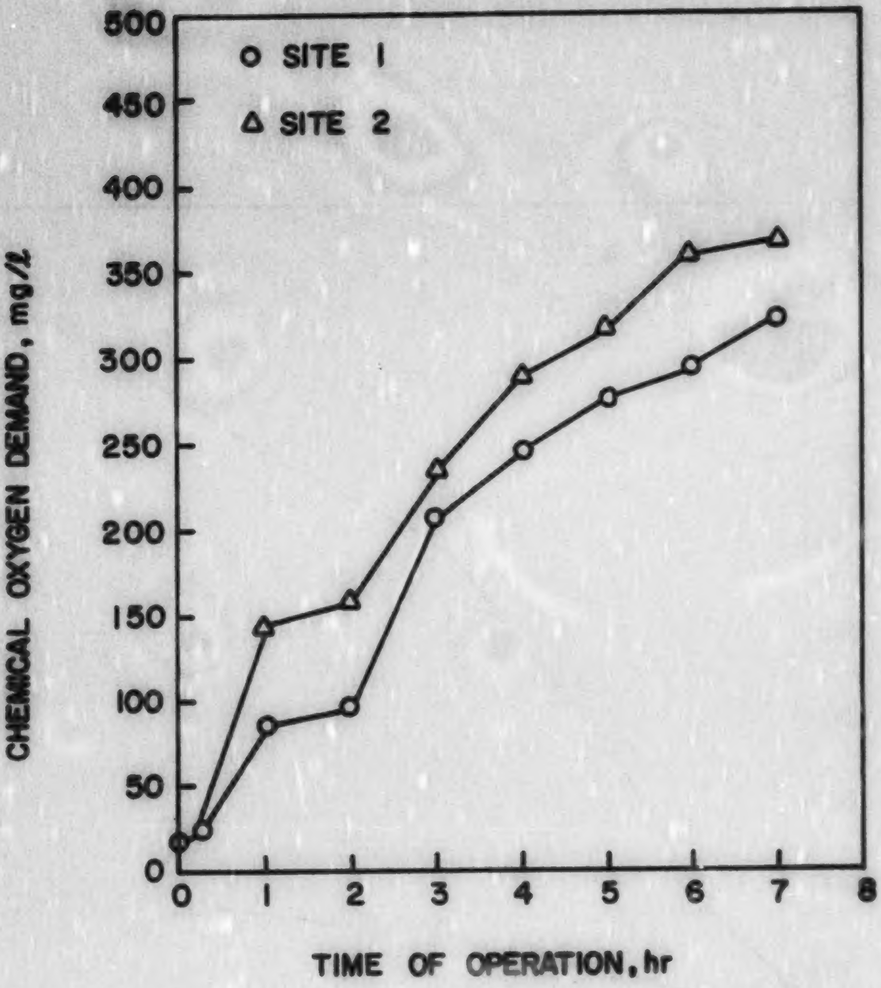

Figure 10. Variations in concentrations of chemical oxygen demand (COD) in water in the first washer. The area between the two curves represents the COD added to the wash water as collards passed through during one day's operation.

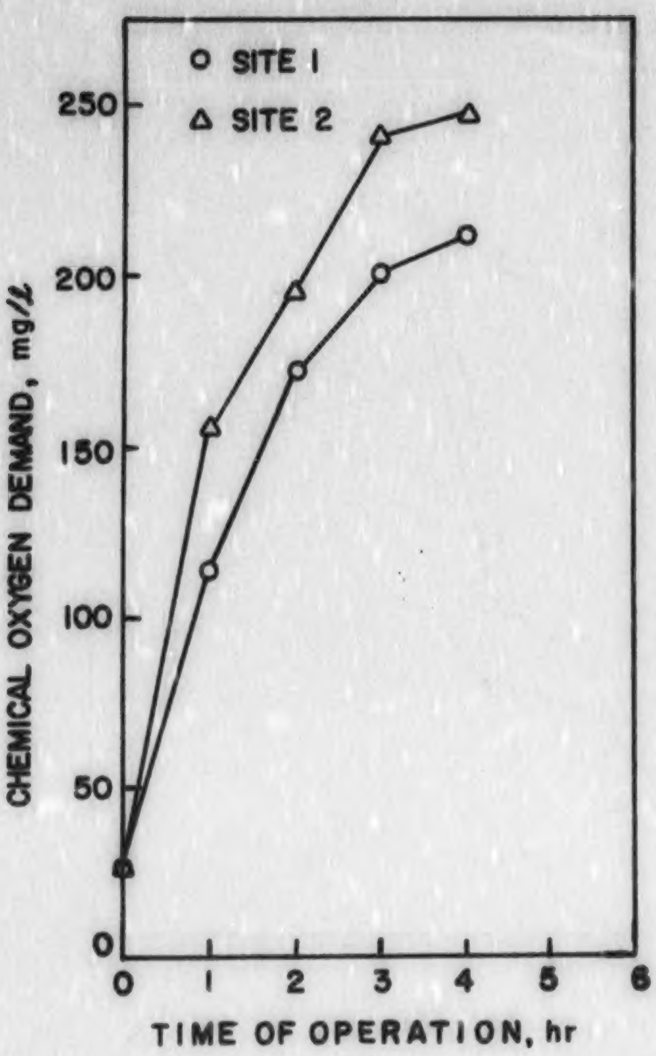

Figure 11. Variations in concentrations of chemical oxygen demand (COD) in water in the first water. The area between the two curves represents the COD added to the wash water as spinach passed through during one day's operation.

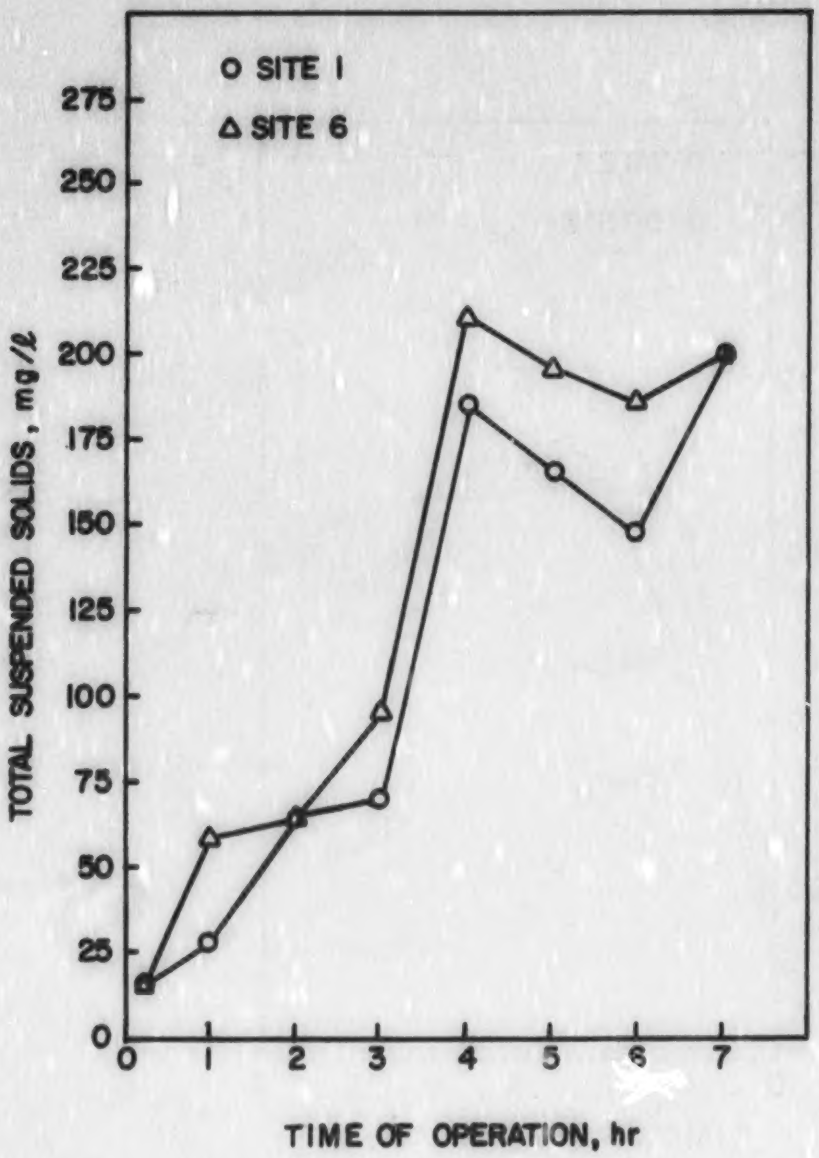

Figure 12. Variations in concentrations of total suspended solids in wash water before and after passage through the first settling basin. The area between the two curves represents the apparent removal of suspended solids by the settling basin during one day's operation when collards were being processed.

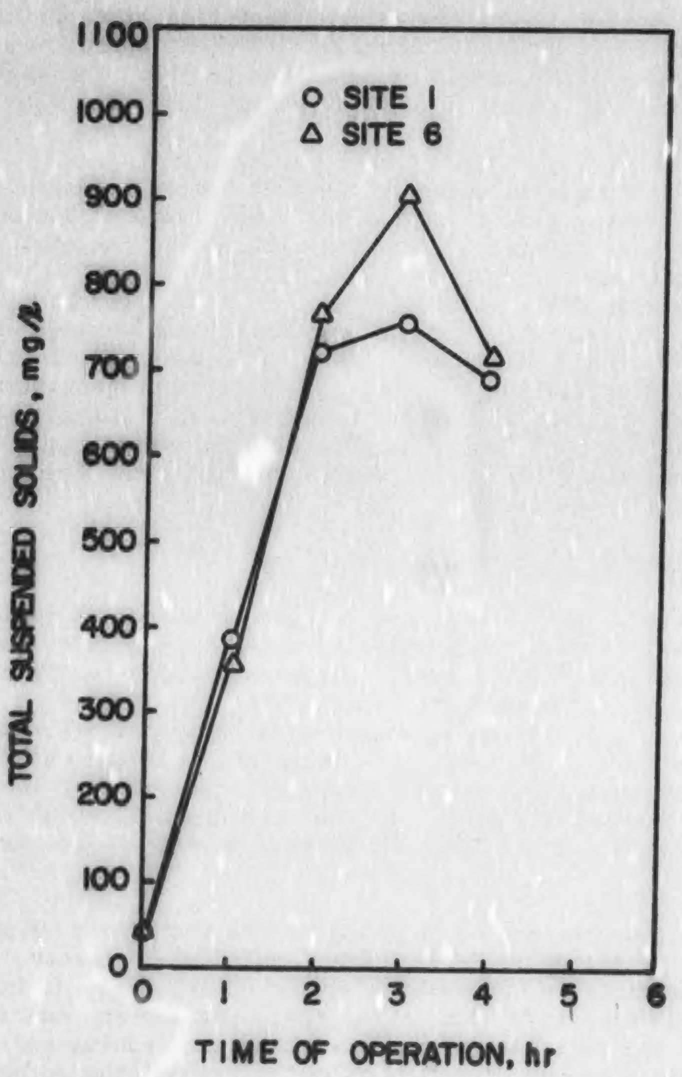

Figure 13. Variations in concentrations of total suspended solids in wash water before and after passage through the first settling basin. The area between the two curves represents the apparent removal of suspended solids by the settling basin during one day's operation when spinach was being processed.

tank, was greater than 2000 mg/ℓ per hour. From Figures 12 and 13, it can be seen that the greatest removal observed at any time appeared to have been less than 50 mg/ℓ.

The distribution of grit in the system showed that most of the larger sediment particles (sand) settled out in the washers before the water ever reached the settling basin. The average detention time in the settling tanks was approximately 7 min, but the intermittent flow of water from the sumps to the settling tanks probably produced sufficient turbulence to reduce the effectiveness of the settling tanks for trapping the smaller particles, that is, the silt and clay (2 to 50 nm and less than 2 nm, respectively).

The data showing changes in concentrations of volatile suspended solids through the settling tank indicated that their removal was poor. These solids are the tiny, leaf constituents, produced by the violent washing action, which pass through the moving filter belts into the settling tanks. Their specific gravity is much less than the inorganic sediment and, while the volatile fraction of the grit recovered from the bottom of the tanks was not determined, it was not unexpected, in light of the particle-size distribution of the grit, that the organic particles were recirculated and not settled. It is possible that chemical coagulant aids, such as organic polymers, would be effective in increasing the settling efficiency of these tiny particles; settling of the fine inorganic particulates also would be aided.

Bacteriological Quality of Wash Water and Product

Table 5 is a summary of the observed changes in bacterial quality of product and wash water through the washing system during four or the five trials. No bacterial densities on product were determined during the first trial washing of collards. Note from the table that the bacterial densities in the washwater on some occasions increased even though chlorine was maintained at a reasonably high level. The greatest increase was observed when the chlorine concentration decreased to zero. In spite of the high total plate counts in water during all trials (average 2.75×10^5 colonies per ml, range 1.7×10^3 to 1.3×10^6) the product itself always was cleaned well.

In addition to the presence of chlorine in the wash water, a second factor may account for the decrease in product total plate counts. A foam was observed to accumulate in the washing system during each washing trial, the accumulation beginning very soon in the operating day and continuing to increase throughout the day. It is suspected that the foaming action was evidence that organic compounds leaching from the greens behaved as surface-active agents and caused additional cleaning by detergent action. Thus, even though the wash water generally became more heavily contaminated with bacteria as more and more product was washed, the product itself was always cleaner after washing than when it was first introduced into the system.

TABLE 5. COMPARISONS* OF BACTERIAL POPULATION DENSITIES (TOTAL PLATE COUNTS) IN WASH WATER AND ON PRODUCT BETWEEN SAMPLES TAKEN FROM THE HEAD OF THE FIRST WASHER AND THE BACK OF THE SECOND WASHER AT THE BEGINNING AND END OF A GREENS-WASHING TRIAL

Trial	Water		Product		Total Chlorine, mg/ℓ**	
	Beginning***	End***	Beginning***	End***	Beginning	End
2	+243%	+380%	-11%	>-99%	2.6	0
3	-64%	-68%	-96%	-68%	0.4	2.3
4	-50%	-61%	>-99%	-67%	1.2	2.3
5	-58%	+76%	>-99%	-68%	1.3	1.6

* A plus sign before a number indicates an increase in bacterial density from the head to the back of the washing system. A minus sign indicates a decrease.

** Residuals measured amperometrically and are the concentrations measured at the back of the second washer at the beginning and end of the processing period.

*** "Beginning" signifies a sample taken within the first hour of operation. "End" signifies a sample taken immediately before termination of the trial.

The differences in the reductions on product at the beginning and end of a washing operation, shown in Table 5, are somewhat misleading because, for some unexplained reason, bacteria populations on the last loads of product being fed to the system were 25 times higher than those on the first loads, averaging 3.3×10^5 colonies per gram and 1.3×10^4 colonies per gram, respectively.

While the total counts of bacteria on product leaving the second washer ranged from 4.6×10^3 to 1.1×10^6 per gram, it should be remembered that the product had not been blanched. Blanching does reduce the population densities to much lower levels.

Insect Removal Efficiency

The insect densities on the fresh cuttings of collards and spinach that were processed during this project were too low for there to be any real test of the insect-removal efficiency of the experimental system. Fall crops, compared to spring, are always less heavily infested with insects.

The maximum number of insects observed during four collard-processing operations was 2 per 100 g of product. During the spinach-processing trial, the maximum observed was 12 per 100 g. Frey et al.(4) reported an average of 65 aphids and 63 insect fragments per 100 g of spinach harvested in spring on the Eastern Shore of Virginia. Washings of spring crops with the experimental system used in this project are planned for the future.

SUMMARY AND CONCLUSIONS

It may be concluded that the experimental washing system, as a whole, performed well during the four trials with collards and the one with spinach. While the water quality did deteriorate as more and more greens were processed, cleaning of the greens while they passed through the system was evident at all times. Reduction of bacterial population densities on the greens were observed in all trials, probably because chlorine residuals were maintained at high levels and because of a detergent action in the washwater induced by dissolved organic compounds leached from the vegetables.

Conclusions derived from this study are:

1. Most of the actual cleaning of product occurred in the first subsystem; an average 71 per cent of organic and inorganic waste water constituentswere present in the first washer and settling basin.

2. The settling tanks were effective in removing small particles such as silt and fine sand. In one trial when sufficient grit for analysis was recovered, 63 per cent of the total was found in settling tank No. 1. Washer No. 1 collected the most of the fine and medium sand (12 per cent of the total weight of grit collected). Differences in total suspended solids concentrations in the wash water from the head to the back of a settling tank did not accurately reflect the actual solids removal that occurred.

3. There were distinct differences in final wash water quality when different cutting of collards were processed, the differences most probably being a function of product maturity.

4. The water-usage rate in the experimental system, was, on the average, 15.6 gal/min (59.0 ℓ/min), which is 77 per cent less than that of the commercial washers at Exmore Foods, Incorporated, where this study was conducted. Water use per unit product was an average of only 0.56 gal/lb (4.66 ℓ/kg) compared to an estimated usage of 1.5 - 2.5 gal/lb (12.5-20.8 ℓ/kg) at Exmore Foods.

5. The average chemical concentrations of the wash water being discharged from the system at the end of the trials were high, both in organic and inorganic suspended solids (110 and 61 mg/ℓ, respectively, when collards were washed and 632 and 57 mg/ℓ, respectively, when spinach was washed). The magnitudes of the solids concentrations probably reflect the fact that

there was considerable turbulence in the settling tanks because of the high recirculation rates within the system and because the lighter particulates (clay and small leaf fragments, e.g.) did not settle well.

6. The average concentrations of COD and BOD_5 in waste water being discharged from the system at the end of the trials were similar to those of weak municipal sewage, averaging 356 and 80 mg/ℓ, respectively, when collards were processed, and 211 and 46 mg/ℓ, respectively, when spinach was washed.

7. Concentrations of both organic and inorganic compounds in wash water were much lower than those reported by Bough(3), as were the waste loads generated per unit weight of product processed. The best agreement of data between the two studies was for total suspended solids. Bough's values for organic waste loads (COD and BOD, lb/ton) were from 5 to 6 times higher than those calculated for this study.

8. Recirculation of wash water in immersion-type, leafy-green washing systems is a promising modification of existing processing methods for reducing water consumption and concentrating waste loads so that they can be more easily treated.

ACKNOWLEDGEMENTS

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TOMATO FLUME WATER RECYCLE WITH OFF-LINE MUD REMOVAL

George E. Wilson[1], Wally R. Rose[2], Jerry Y. C. Huang[1]

SUMMARY AND CONCLUSIONS

The wastewater management objective for a tomato processor is to implement sound and performance guaranteed systems which minimize wastewater related costs. Using performance parameter values found in this project, it was demonstrated that installation and operation of an in-plant water recycle system with off-line mud removal would result in approximately 50% savings in the total annual wastewater related costs. For the 35 ton/hr plant evaluated, annual savings would amount to approximately $47,000.

The '75 season performance parameter values were obtained from investigation of four modes of operation; conventional cleaning; conventional cleaning with water recycle; disc cleaner with water recycle; and, disc cleaner with recycle and chemical coagulation-flocculation. Water consumption and total solids balances were made on each mode.

Not surprisingly the daily average tonnage of tomatoes processed increased substantially with disc cleaning and water recycle as compared to the conventional system. An increase of 26% in the tonnage of tomatoes processed was realized with the disc cleaner with water recycle and chemical flocculation. These increases in the daily tonnage of tomatoes processed may be primarily due to the virtual elimination of solids accumulation in the dump tank with consequent impaired product flow. No incident of temporary shutdown of shift operation for dump tank clean-up was encountered during the modes of operation with water recycle.

With respect to the water consumption, the following findings were established in this study:

1. The majority of daily water usage was operational (48-61%) followed by clean-up (31-44%) and filling (6-8%). There were no significant variations in percentage usage in the various modes of operations. In all modes of operation approximately 7% was filling; approximately 55% operational; and approximately 39% clean-up.

2. A 26% decrease in the average total daily water usage was realized when disc cleaner with water recycle and chemical flocculation relative to the conventional system was applied.

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[1] EUTEK, INC., Process Development and Engineering, Sacramento, CA.
[2] National Canners Association, Berkeley, CA.

3. A decrease in the average unit water consumption rate relative to counter-current flow conventional cleaning occurred when water recycle measures were applied. A 41% decrease in average unit water consumption rate was realized when the disc cleaner with water recycle and chemical flocculation (164 gal/ton) was applied relative to the conventional system (278 gal/ton).

With respect to the total solids balances, the following conclusions were drawn:

1. With the water recycle measures implemented, the soil solids removed from the dump tank per tonnage of tomatoes processed were significantly reduced; the soil solids lost to the sewer per tonnage of tomatoes processed were reduced substantially.

2. The estimated soil solids incoming to the plant per unit weight of tomatoes processed ranged from 10 to 20 lbs/ton, having an average of 13 lbs soil solids per ton of tomatoes processed. The total soil loaded was estimated from the sum of soil solids which were collected from the dump tank, lost to the sewer, and removed from the sludge thickener. It appeared that the amount of soil to the plant varied considerably, depending on the type of soil from which the tomatoes were grown, the moisture content of the soil when the tomatoes were harvested, and the method of tomato harvesting.

3. Efficient clarification of the thickener overflow requires surface loading rates of less than 1,000 gpd/ft^2. Approximately one-half of the gravity settleable soil solids overflowed from the thickener at surface loading rates of 2,000 gpd/ft^2.

INTRODUCTION

With the advent of mechanical harvesting of tomatoes, tomato processors noted an increase in the soil accumulations within the flume system. Most of the soil accumulated in the initital flumes or bin dumps. Velocities within the bin dump were insufficient to scour settled soil solids from the base. The resultant accumulation of soil in the bin dump eventually impaired product flow and required processing downtime to remove.

There are two widely practiced procedures for mitigating the accumulation of soil in the bin dump. The first is to employ a high overflow rate from the bin dump, this overflow discharging to the plant's sewer system. The second procedure involves processing downtime to drain off excess liquids and hand shovel the accumulated soil into an adjacent receptacle.

Several adverse impacts result from the current procedure for handling bin dump mud. In the case of the high overflow rates, the excess water used adds to the hydraulic surcharge to the sewer system from this seasonal industry. The high soil loadings discharged to municipal treatment systems result in operation and maintenance problems. As a consequence of the necessity for periodically shutting down the bin dump to remove accumulated soil, the time requirements for processing a given tonnage of tomatoes are extended resulting in reduction of the plant's productivity. This, in turn, results in further excess water use through the down-time period and for the additional required cleanup and washdown.

Project Objectives

During the 1974 processing season, a jointly sponsored EPA-NCA project was undertaken to evaluate alternative water recycle system configurations. Bin dump model studies were then undertaken in the spring of 1975 to develop design data on an efficient system for intercepting soil solids in the bin dump and transporting them to the solids removal system without interfering with product flow.

The objective of the '75 season tomato water recycle project was to demonstrate a water recycle system which when used in conjunction with a normal bin dump operation would significantly reduce the adverse impacts associated with current practices. An essentially closed loop recycle system was employed. The recycled water was used to maintain adequate scouring velocities within the bin dump without detrimentally affecting product flow. A solids removal system was constructed within the closed loop to remove the settleable solids and thereby prevent their accumulation within the bin dump. This recycle system was expected to eliminate excessive water usage related to high bin dump overflow rates as well as those related to clean-up down-time and extended operational period for processing a given tonnage of tomatoes.

Process Design, Operation, and Data Acquisition

Facility Design and Installation

The key process elements were a solids trapping false bottom; an ejector for solids transport; a screen with screenings discharge hopper; a soil solids separating swirl concentrator; a sludge thickener; and a chemical coagulation-flocculation system. As shown on Figure 1, the soil solids passed through the false bottom and were transported by an ejector to the gravity screen. Here vines, rocks, and debris were separated and the settleable soil solids in the water were routed to the swirl concentrator. Solids within the swirl concentrator under-flow were further concentrated within the sludge thickener. A mechanical device was provided to enhance the gravity thickening process. Thickened sludge was removed from the bottom of the thickener for final disposal.

The swirl concentrator overflow was recycled to the bin dump through standpipes to provide a motive force for both the bin dump scour jets and the solids transporting ejector. The sludge thickener supernatant was returned as make-up water to the bin dump or was discharged to the sewer. The general configuration of the required modifications to existing bin dump tanks is illustrated on Figure 2. This configuration was developed

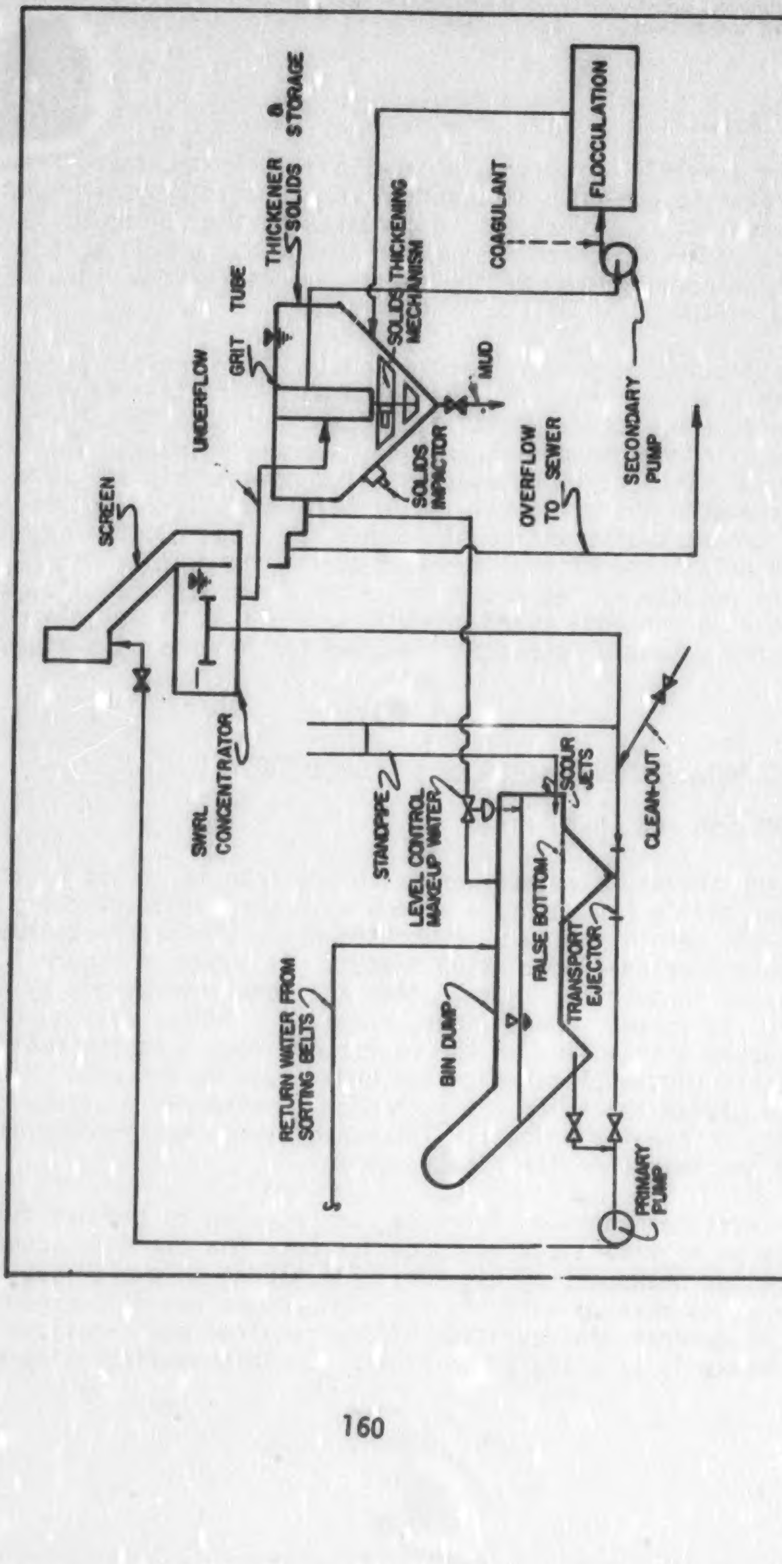
RETURN WATER FROM SORTING BELTS
BIN DUMP
FALSE BOTTOM
TRANSPORT EJECTOR
PRIMARY PUMP
LEVEL CONTROL MAKE-UP WATER
STANDPIPE
SCOUR JETS
CLEAN-OUT
SWIRL CONCENTRATOR
SCREEN
UNDERFLOW
GRIT TUBE
THICKENER
SOLIDS
&
STORAGE
SOLIDS THICKENING MECHANISM
SOLIDS IMPACTOR
MUD
OVERFLOW TO SEWER
SECONDARY PUMP
COAGULANT
FLOCCULATION

FIG.1 FLOW DIAGRAM OF WATER RECYCLE SYSTEM

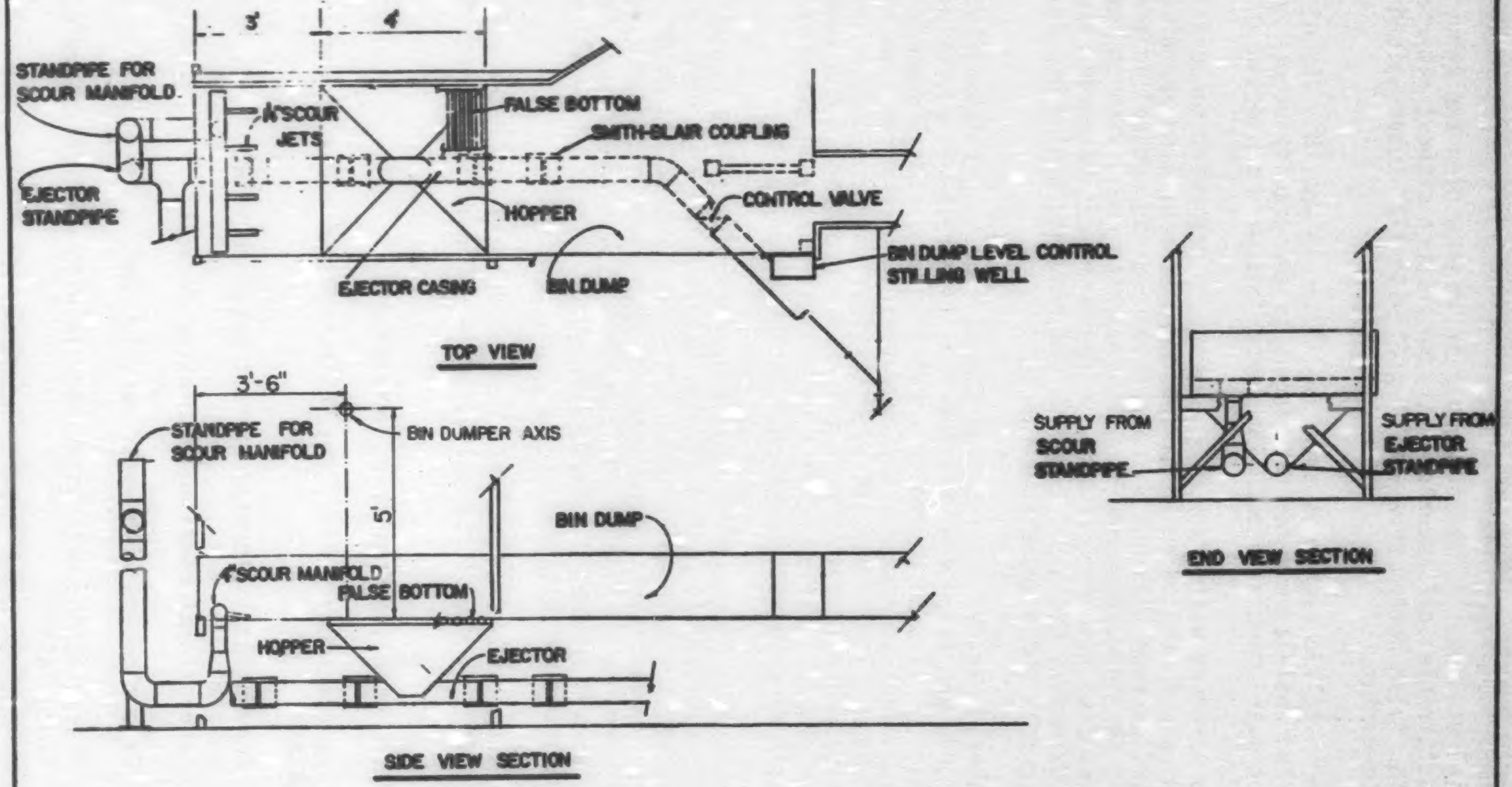
3'
4'
STANDPIPE FOR SCOUR MANIFOLD.
1/4"SCOUR JETS
FALSE BOTTOM
SMITH-BLAIR COUPLING
EJECTOR STANDPIPE
HOPPER
CONTROL VALVE
BIN DUMP LEVEL CONTROL STILLING WELL
EJECTOR CASING
BIN DUMP
TOP VIEW
3'-6"
STANDPIPE FOR SCOUR MANIFOLD
BIN DUMPER AXIS
5'
BIN DUMP
4"SCOUR MANIFOLD
FALSE BOTTOM
HOPPER
EJECTOR
SIDE VIEW SECTION
SUPPLY FROM SCOUR STANDPIPE
SUPPLY FROM EJECTOR STANDPIPE
END VIEW SECTION

FIG 2 FULL SCALE GRIT COLLECTOR & TRANSPORT SYSTEM DESIGN

from model studies.(1) It is capable of intercepting and removing 80%+ of the settleable soil entering with the product without altering product flow. The false bottom area was 4' x 4' with 1/2" tubes spaced at 1-1/4" center-to-center.

The installed system is shown on Plates 1A and 1B. The ejector-transported soil-laden water was pumped to the gravity screen mounted above the swirl concentrator. The screenings were collected in a gondola.

The screened water flowed by gravity to the swirl concentrator.(2) Grit and sand in the incoming wastewater were separated and discharged with the underflow from this unit. An orifice opening controlled the underflow rate. As designed, the underflow rate was 100 gpm. With the maximum design incoming flow rate of 500 gpm the swirl concentrator overflow rate was approximately 400 gpm. Overflow was returned to the bin dump through the scour jets and transporting ejector.

Underflow loaded the ten foot diameter gravity thickener at approximately 2,000 gpd/ft^2. The thickener overflow rate was approximately equivalent to the swirl concentrator underflow rate. Level control was provided at the dump tank to regulate the amount of thickener overflow returned to the system. This prevented overflow from the bind dump. When the bin dump was topped-off, thickener overflow was bypassed to the sewer. This assured a single overflow point from the water recycle system to the sewer. Only clarified water was discharged to the sewer.

In order to increase the thickener underflow solids concentration a vibrating thickening mechanism was installed to break down bridging of solids within the thickening zone. Vibration was activated by pneumatic impactors. In addition to the internal mechanism an impactor was mounted externally on the cone of the thickener to assist the flow of solids to the cone apex. Pneumatic impactors provided impacts at 60-psi pressure at controlled time intervals.

Thickener underflow was withdrawn periodically through a 6" diaphragm valve. Underflow sludge was collected in gondolas for subsequent disposal.

Operational Modes and Monitoring Arrangement

During the study period, the following four modes of operation were investigated:

1. Conventional cleaning without water recycle;

2. Conventional cleaning with water recycle;

3. Disc cleaning with water recycle; and,

4. Disc cleaning with water recycle with chemical coagulation-flocculation.

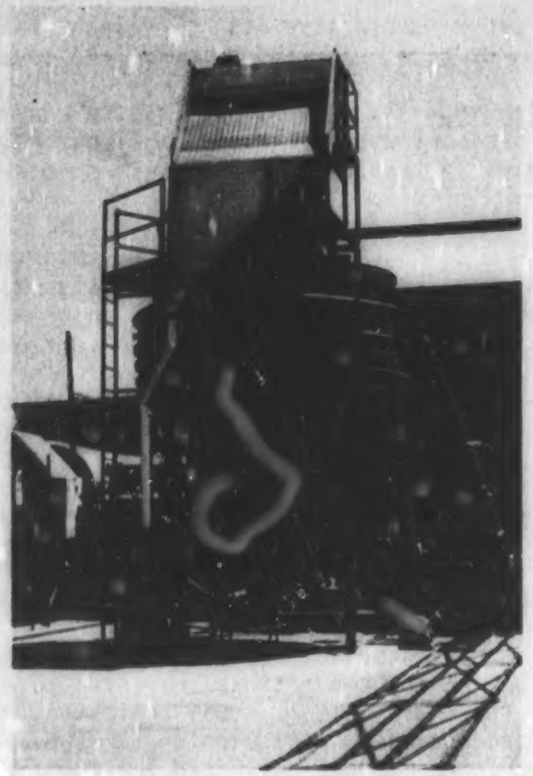

PLATE 1A VIEW OF IN-TAKE PUMP, SCREEN, SWIRL CONCENTRATOR, SLUDGE THICKENER AND TUBE FLOCCULATOR

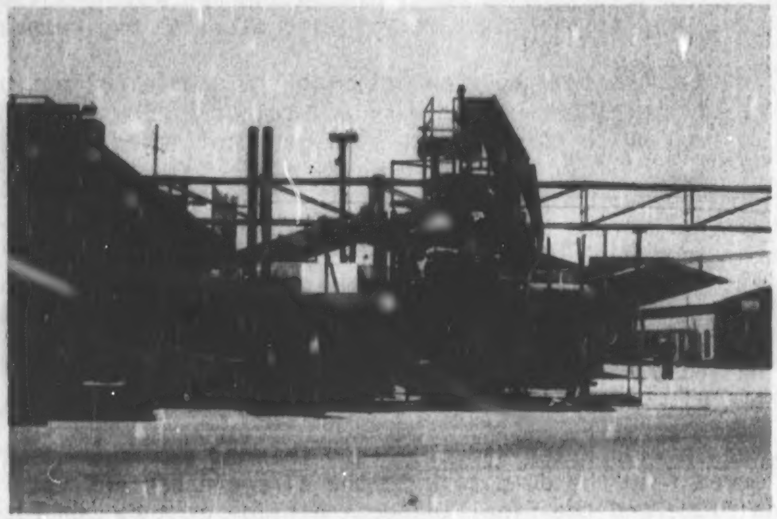

PLATE 1B GENERAL VIEW OF WATER RECYCLING FACILITIES

The monitoring program objective was to evaluate each of the four modes of operation in terms of total water consumption and total soil solids removed.

Conventional Cleaning--The conventional system consisted of four stages: dump tank, inside flume, distribution flume and, final rinse step. Tomatoes were mechanically transported by elevators between stages.

As shown on Figure 3, counter-current use of water was employed in the conventional system. The distribution flume water was recycled between the distribution flume and tank-3. A portion of water equal to the final rinse was pumped to the inside flume. Excess inside flume water flowed by gravity to tank-1. There was an internal recycle loop between tank-1 and the dump tank. Excess water overflowed from tank-1 to the sewer. A significant savings in water consumption had already been realized in the counter-current mode of operation relative to systems in which each stage operates independently. Composite water samples were collected from the tanks on each loop such that water quality represented the water in each of the flumes as designated 5W from the dump tank, 2W from the inside flume and 6W from distribution flume. There were a total of five flow meters monitoring the various flow rates.

The water samples were used to determine the solid concentrations for mass balances. During the conventional cleaning mode a steal plate was placed on top of the false bottom. Soil solids accumulated within the dump tank were hand shoveled into gondolas for subsequent disposal. Soil samples from the gondolas were collected for the solid concentration determinations.

Conventional Cleaning with Water Recycle--In this mode of operation, the water recycle system was added to the conventional mode of operation. Soil solids were intercepted by the false bottom and were transported by the ejector and pump to the water recycle and off-line mud removal system.

On Figure 4 are shown the flow metering the sample collection points for this mode of operation. There were a total of 8 flow meters and 10 sample points from which composite samples were collected for water quality analyses.

Irregular deliveries of field harvested product occurred during this mode of operation. As a consequence, the plant frequently operated with partial shifts. Oftentimes the processed tomato tonnage was significantly less than the plant's capacity. Thus, while effective interception, transport, and removal of settleable soil was effected by the water recycle system, its affect on the productivity of the plant and the full ramifications on water use was not accurately assessed.

Disc Cleaner With Water Recycle --In this mode of operation, tomatoes were transferred from the dump tank to the disc cleaner and then to the distribution flume and the final inspection stage as shown on Figure 5.

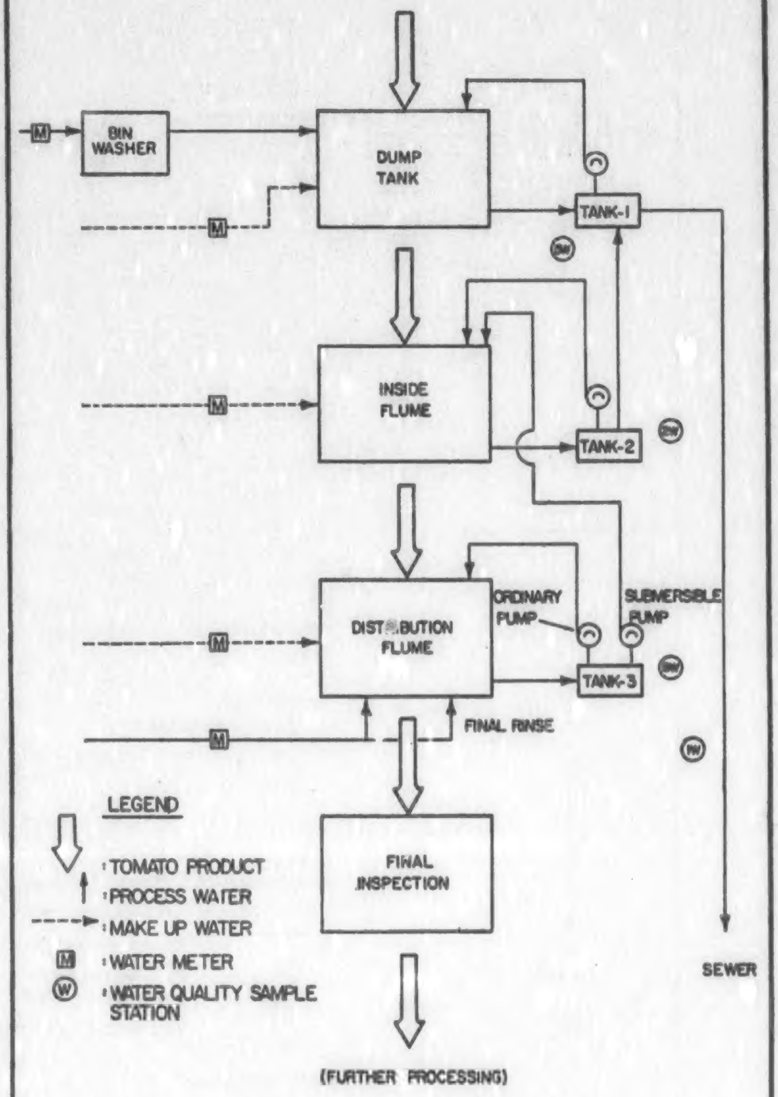
M
BIN WASHER
DUMP TANK
M
TANK-1
W
INSIDE FLUME
M
TANK-2
W
DISTRIBUTION FLUME
ORDINARY PUMP
SUBMERSIBLE PUMP
M
TANK-3
W
M
FINAL RINSE
W
LEGEND
TOMATO PRODUCT
PROCESS WATER
MAKE UP WATER
M WATER METER
W WATER QUALITY SAMPLE STATION
FINAL INSPECTION
SEWER
(FURTHER PROCESSING)

FIG.3- FLOW DIAGRAM OF CONVENTIONAL CLEANING SYSTEM

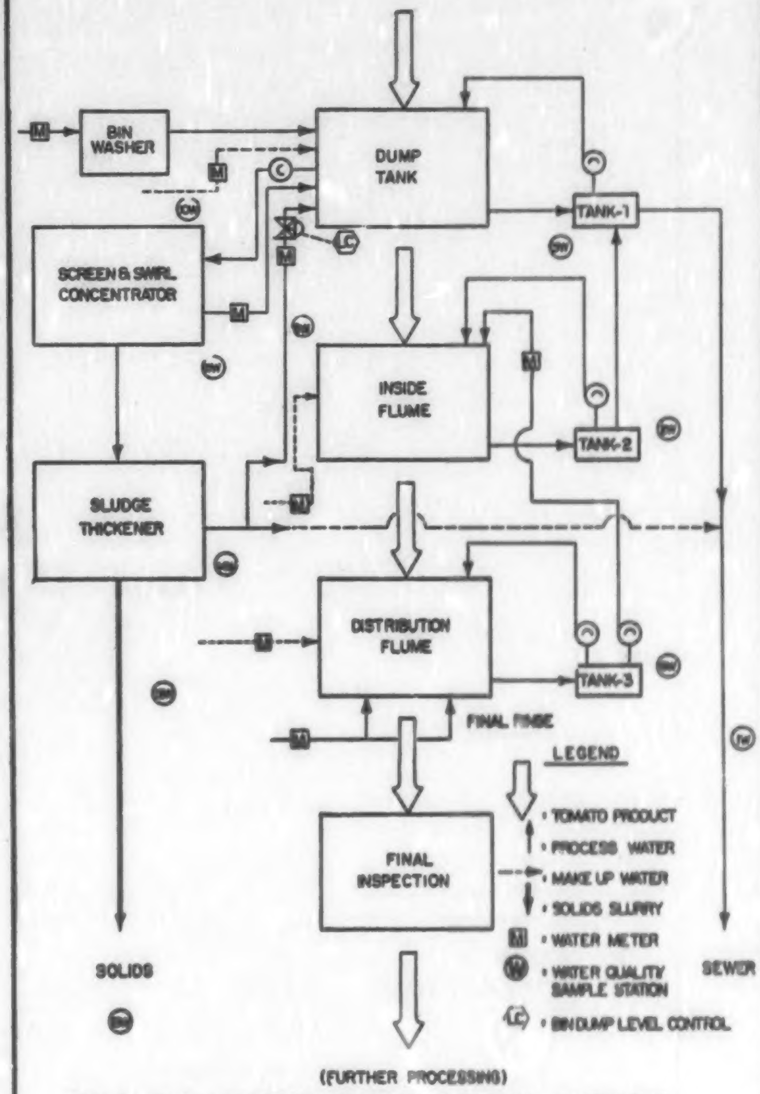
M
BIN WASHER
DUMP TANK
M
C
LC
TANK-1
SCREEN & SWIRL CONCENTRATOR
M
INSIDE FLUME
M
TANK-2
SLUDGE THICKENER
M
DISTRIBUTION FLUME
M
TANK-3
M
FINAL RINSE
LEGEND
= TOMATO PRODUCT
= PROCESS WATER
= MAKE UP WATER
= SOLIDS SLURRY
M = WATER METER
W = WATER QUALITY SAMPLE STATION
LC = BIN DUMP LEVEL CONTROL
FINAL INSPECTION
SOLIDS
SEWER
(FURTHER PROCESSING)

FIG.4- FLOW DIAGRAM OF CONVENTIONAL CLEANING WITH WATER RECYCLE SYSTEM

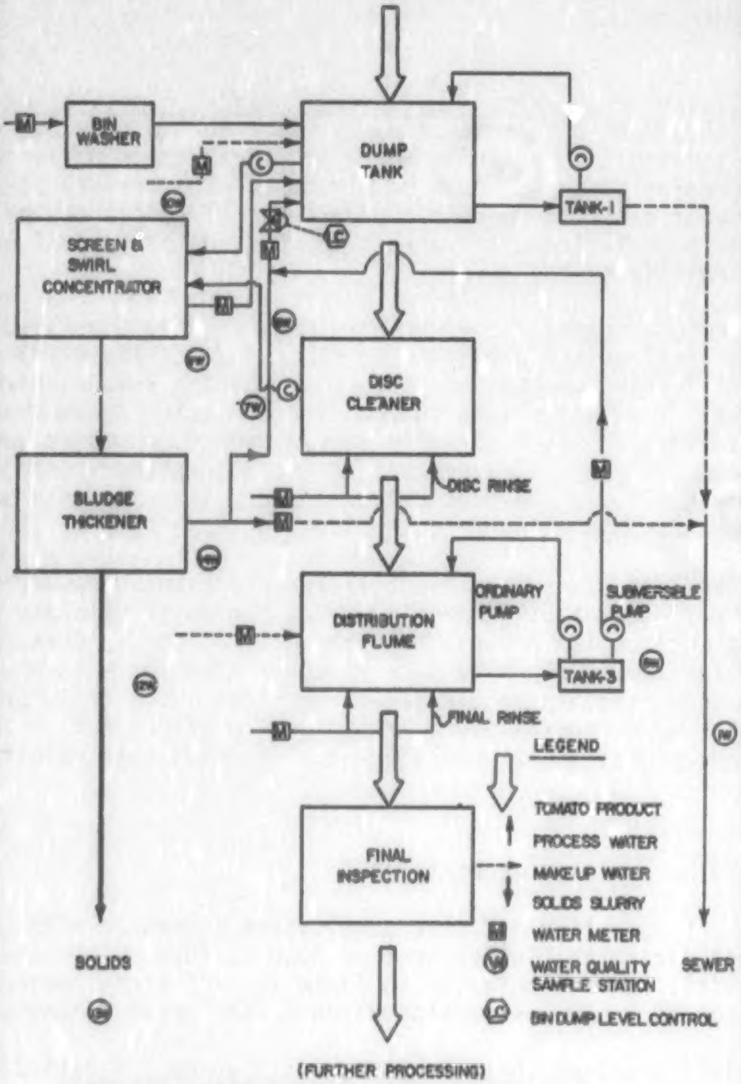
BIN WASHER
DUMP TANK
TANK-1
SCREEN & SWIRL CONCENTRATOR
DISC CLEANER
SLUDGE THICKENER
DISC RINSE
DISTRIBUTION FLUME
ORDINARY PUMP
SUBMERSIBLE PUMP
TANK-3
FINAL RINSE
FINAL INSPECTION
SOLIDS
SEWER
(FURTHER PROCESSING)
LEGEND
TOMATO PRODUCT
PROCESS WATER
MAKE UP WATER
SOLIDS SLURRY
WATER METER
WATER QUALITY SAMPLE STATION
BIN DUMP LEVEL CONTROL
M
C
LC
WQ

FIG.5 - FLOW DIAGRAM OF DISC CLEANER WITH WATER RECYCLE SYSTEM

The disc cleaner replaced the inside flume conventional cleaning process to remove tightly adherent smear soil. In this unit the long exposure of tomatoes to the turbulent action of water was replaced by short exposure to the vigorous mechanical shipping action of soft rubber discs.(3) The action of the discs moved the tomatoes through the unit, loosened and shipped off the soil and threw the heavy soil water into the tray beneath the device. The rubber disc unit was equipped with small whirl jet spray nozzles, located to provide full coverage of the last 2 feet of the unit with no overlap. Water was collected and pumped to the gravity screen and swirl concentrator.

Disc Cleaner With Water Recycle and Chemical Flocculation--The flow diagram in this mode of operation was similar to the previous flow scheme except for the addition of the internal chemical coagulation and flocculation at the thickening stage as shown on Figure 6. The primary study objective in this mode of operation was to evaluate the effectiveness of chemical coagulation-flocculation with respect to soil solids removal efficiency and wastewater quality to the sewer.

The chemical coagulation-flocculation mechanism consisted of four components: recirculation pump, tube flocculator, slip-stream turbidimeter, and chemical feeding mechanism. The recirculating pump withdrew from the grit tube, a 10" diameter tube surrounding the swirl concentrator underflow. Grit settled through the tube while turbid underflow waters were withdrawn. A portion of the flow was directed into the slip-stream turbidimeter which continuously monitored the turbidity. The chemical feed was automatically controlled to be proportional to the level of turbidity of the water.

The coagulant mixing and flocculation processes were accomplished in a novel tube flocculator(4) comprised of a series of discrete pipe sections. These pipes were coiled around the outer wall of the thickener, each downstream section having a progressively larger diameter with diverging transition members connecting adjacent sections. The coil curvature and pipe diameter were carefully pre-determined to effect a flow condition velocity gradient yielding optimum coagulation-flocculation results in minimum time.

Plant Operation and Data Acquisition

The plant operation and data acquisition commenced with the tomato season start during the latter part of August, 1975. The schedule of operations are listed chronologically in Table 1. The study period covered the entire season of tomato processing which lasted about 2 months.

The plant operated three 8-hour shifts per day, 6 days per week. There were approximately 4 operators involved in each shift. One operator was controlling the rate of tomatoes to the bin dump and the other three operators were involved in the following tasks:

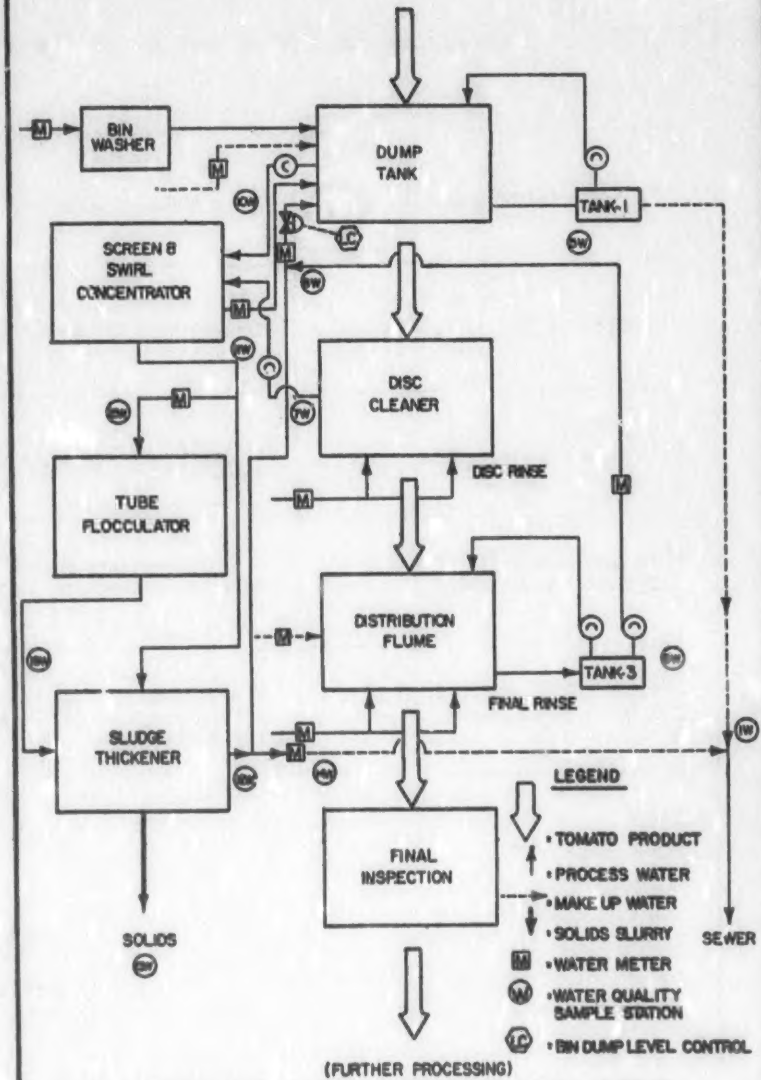
BIN WASHER
DUMP TANK
TANK-1
SCREEN & SWIRL CONCENTRATOR
DISC CLEANER
DISC RINSE
TUBE FLOCCULATOR
DISTRIBUTION FLUME
TANK-3
FINAL RINSE
SLUDGE THICKENER
FINAL INSPECTION
SOLIDS
SEWER
(FURTHER PROCESSING)
M
10W
5W
8W
9W
7W
1W
LEGEND
• TOMATO PRODUCT
• PROCESS WATER
• MAKE UP WATER
• SOLIDS SLURRY
• WATER METER
• WATER QUALITY SAMPLE STATION
• BIN DUMP LEVEL CONTROL

FIG.6- FLOW DIAGRAM OF DISC CLEANER WITH WATER RECYCLE SYSTEM WITH FLOCCULATION

TABLE 1

CHRONOLOGICAL LISTING OF THE MODES OF OPERATION

Period of Operation	Modes of Operation
3 Sept - 9 Sept, 1975	Conventional Cleaning
10 Sept - 14 Sept, 1975	Conventional with Water Recycle
16 Sept - 20 Sept, 1975 & 30 Sept - 8 Oct, 1975	Disc Cleaner with Water Recycle
22 Sept - 29 Sept, 1975 & 9 Oct - 11 Oct, 1975	Disc Cleaner with Water Recycle and Chemical Coagulation-Flocculation

1. Organization of tomato bins for processing;
2. Removal of vines and debris from vine collectors;
3. Maintaining and clean-up of the processing facilities.

Three full-time NCA operators, one in each shift, were at the plant throughout the study period. The duties of these operators were:

1. Taking water meter readings at the beginning and end of each shift;
2. Taking sludge samples, one at each shift;
3. Taking tomato product samples in each shift at each washing stage;
4. Recording events and general observations;
5. Recording total number of bins processed;
6. Tabulating results.

ISCO automatic water samplers were used at all sampling points except two, one at the influent water to the swirl concentrator and the other at the sludge thickener overflow. At these sampling points, an automatic Roto Vee sampler developed by EUTEK was used. The Roto Vee sampler consisted of sample collector, motor and remote controlling timer. The Roto Vee, because of its simple design and operation, was effective in collecting samples having relatively high solids concentrations such as the wastewater incoming to the swirl concentrator. Sampling for sludge solids concentrations was done with a core sampler which collected representative mud samples from deposited soil solids.

Interpretation of Results

Analysis of Water Consumption

Water usage in a typical tomato processing plant can be categorized as:

1. Filling
2. Operation or process
3. Clean-up

Filling water represented that used to fill the dump tank and flumes. It was normally required at the end of each washing period and prior to the beginning of the following operation shift. Process water used for operation was that which was continuously utilized during the shift operation, such as bin wash, continuous spray onto trash belts for cleaning purposes and final rinse waters. Clean-up water was used both during the operation period for cleaning floors and for clean-up tanks, flumes and other equipment during the normal clean-up period. Total water consumption in a typical tomato processing plant was the sum of all the water used for each above-mentioned purpose.

The Average Water Consumption Rates--The total and unit water consumption rates have been averaged and summarized in Table 2.

In the conventional cleaning mode, which represented an average of six days operations, the average amount of tomatoes processed was 481 ton/day; total water usage was 133,500 gal/day; yielding an average unit water consumption rate of 278 gal/ton of tomatoes processed.

As indicated on Figure 3, the conventional cleaning system utilized an effective counter-current flow scheme, thereby reducing total plant water usage significantly below that of other tomato plants. Conventional tomato plants without counter-current use of process waters have been reported to utilize approximately 1200 gal/ton of tomatoes processed.(5) Significant savings in water volume used can be achieved through utilizing counter-current flow measures. In this study, the comparison of the water recycle system with off-line mud removal was made relative to a system in which maximum water conservation through counter-current measures had already been effected.

The second mode of conventional operation with water recycle averaged over four consecutive days of operation, the average amount of tomatoes processed was 445 ton/day; average water consumption was 109,100 gal/day. The average unit water consumption rate was 245 gal/ton or tomatoes processed.

Due to the intermittent and irregular delivery of field harvested product during this period, the resulting unit water usage rate should be viewed as suspect. Shift operations were frequently limited by quantity of tomatoes to process. It would be expected under normal operating conditions in which quantity of field harvested products did not limit plant operation that the unit water usage in this mode of operation would be similar to that found in the other water recycle modes of operation.

Under the mode of operation of disc cleaning with water recycle, over twelve days of operation, the average amount of tomatoes processed was 594 ton/day and the average water consumption was 92,800 gal/day. The average unit water consumption rate was 156 gal/ton of tomatoes processed. In the final mode of operation of disc cleaning with water recycle with chemical flocculation over eight days of operation, the average amount of tomatoes processed was 605 ton/day; with an average water consumption of 99,000 gal/day. The average unit water consumption rate was 164 gal/ton of tomatoes processed.

Several observations and conclusions can be drawn:

TABLE 2

SUMMARY OF AVERAGE WATER CONSUMPTION BY MODE OF OPERATION

Mode of Operation	Average Tomato Tonnage Processed (ton/day)	Average Water Consumption (gal/day)				Average Unit Water Consumption Rate (gal/ton)
		Filling	Operational	Clean-up *	Total	
Conventional	481	10,700	81,300	41,500	133,500	278
Conventional w/ Recycle - w/o Floc.	445	7,800	59,800	41,500	109,100	245
Disc Cleaner w/ Recycle - w/o Floc.	594	7,000	44,300	41,500	92,800	156
Disc Cleaner w/ Recycle - w/ Floc.	605	6,400	51,100	41,500	99,000	164

* Season Average Value

1. The tonnage of tomatoes processed daily increased substantially during the disc cleaner modes of operation. A 26% increase in the tonnage of tomatoes processed was realized with the disc cleaner with water recycling and chemical flocculation relative to conventional cleaning without recycle. This increase may be due to the increase in the soil solids removal efficiency from the dump tank such that there was no significant accumulation of solids in the dump tank which hindered the tomato processing operation. No incident of temporary shutdown of the operation was encountered during the modes of operation with water recycling measures.

2. A decrease of 26% in average total daily water usage is realized with disc cleaning with water recycle and chemical flocculation relative to conventional cleaning without recycle. Decreases in water usage were noted in both clean-up and operation.

3. A significant decrease in the average unit water consumption rate occurred when disc cleaning with water recycle was applied. A 41% decrease in average unit water consumption rate was realized when disc cleaner with water recycling and chemical flocculation was applied relative to conventional cleaning without recycle.

Table 3 presents the percentage of average water consumption by operation mode. The majority of daily water usage was operational (48%-61%) followed by clean-up (31%-44%) and filling (6%-8%) purposes. There were no significant variations in percentage of daily total under various modes of operation. Approximately 7% of daily water usage was filling; 55% for operational; and, approximately 39% for clean-up purposes.

Flow Balance in Water Recycle Modes--The average flows to the swirl concentrator during each of the three shifts for each operational mode investigated are shown in Table 4. Flows to the swirl concentrator were about 100,000 gal/shift for all three operational modes. Flows were consistently lower during the second shift relative to the first and third shift. There is no apparent explanation.

For the operational modes with water recycle the only source of water discharged to the sewer was the thickener overflow. The average thickener overflow to the sewer (equal to the total make-up water) is also shown in Table 4. The volume of thickener overflow to the sewer was approximately the same for all three water recycle operational modes.

Mass Balance Analysis--On Table 5 are presented the total solid concentrations under the various operational modes. For the dump tank and inside the distribution flumes, there was no significant difference in solid concentrations. However, there was a significant reduction in solid concentration to the sewer with water recycle. Eight thousand mg/l of solid overflowed to the sewer in the conventional cleaning system. Between 800 to 3,000 mg/l of solid overflowed when recycle and reuse measures were used.

TABLE 3

PERCENTAGE OF AVERAGE WATER CONSUMPTION BY OPERATION MODE

Mode of Operation	Filling Purpose	Operational Purpose	Clean-up Purpose	Daily Total
Conventional	8	61	31	100
Conventional w/Recycle - w/o Floc.	7	55	38	100
Disc Cleaner w/Recycle - w/o Floc.	8	48	44	100
Disc Cleaner w/Recycle - w/Floc.	6	52	42	100

TABLE 4

AVERAGE TOTAL FLOW TO SWIRL CONCENTRATOR AND OVERFLOW TO SEWER DURING EACH SHIFT

Mode of Operation	Average Total Flow to Swirl Concentrator						Average Total Overflow to Sewer					
	Shift 1		Shift 2		Shift 3		Shift 1		Shift 2		Shift 3	
	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow	Quant. (gal)	% of Shift Total Flow
Conventional w/Recycle - w/o Floc.	118,600	385	90,200	260	100,700	325	21,500	65	16,900	49	21,400	65
Disc Cleaner w/Recycle - w/o Floc.	124,600	373	105,500	286	102,400	308	15,600	42	17,200	46	18,000	49
Disc Cleaner w/Recycle - w/Floc.	104,800	284	88,300	246	106,800	287	17,800	47	16,500	45	17,600	47

TABLE 5

REPRESENTATIVE SOLID'S CONCENTRATIONS BY OPERATIONAL MODE

Mode of Operation	Dump Tank (mg/l)	Inside Flume (mg/l)	Distribution Flume (mg/l)	From Disc Cleaner (mg/l)	Overflow to Sewer (mg/l)	Into Swirl Concentrator (mg/l)	Overflow From Swirl Concentrator (mg/l)	Slurry From Dump Tank (%)	Slurry From Thickener (%)
Conventional	8,000	750	350	--	8,000	--	--	60	--
Conventional with Recycle	4,000	1,000	300	--	3,000	8,000	7,000	64	30
Disc Cleaner with Recycle	--	--	400	2,000	1,000	6,000	5,000	64	32
Disc Cleaner with Recycle and Chemical Coag-Floc.	--	--	500	2,000	800	7,000	6,000	60	30

The suspended solids concentration in the overflow from the sludge thickener during the '75 season study was two-fold higher than observed during the '74 season study. During the '74 season study, the thickener had been loaded at approximately 1,000 gal/day/ft^2. Turbulence in the thickener was low enough to insure clarification of the swirl concentrator underflow waters. Thickener overflow solids concentrations were approximately 300-500 mg/l. In the '75 season study, the sludge thickener overflow rate was increased to 2,000 gal/day/ft^2. The increased turbulence presumably resulted in an increase in the overflow solids concentrations.
It would appear that to achieve acceptable solids concentrations in the thickener overflow the loading should be maintained at approximately 1,000 gpd/ft^2 or less.

The solids concentration in the influent to the swirl concentrator ranged from 6,000 to 8,000 mg/l for all water recycle modes of operation. The solids to the swirl concentrator were those intercepted by the false bottom and transported by the ejector excluding those separated by the gravity screen. The false bottom was quite effective in intercepting settleable soil solids. In the conventional cleaning mode with recycle the bin dump solids concentration was 4,000 mg/l as compared to 8,000 mg/l in the influent to the swirl concentrator.

Solids separated by the screen were primarily tomato seeds. Approximately 30 ft^3 of solids were collected from the screen daily. Since these solids were primarily generated from broken tomatoes they were not taken into account as soil solids loaded to the plant with incoming raw tomatoes.

Comparing the swirl concentrator overflow solid concentrations with that of influent, it was noted that a reduction of only 1,000 mg/l in solid concentration was realized. This was true for all modes of operation. This result indicated that the majority of the solids were not settleable. The solid removal efficiency by the swirl concentrator was apparently affected by the particle size distribution of the soil, in addition to the other design parameters. The particle size distribution was, in turn, dependent on the type of soil from which the tomatoes were grown. The type of soil, the moisture content of the soil when the tomatoes were harvested and the method of tomato harvesting all affected the amount of soil solids carried to the processing plant. These "unaccountable" factors might explain the variations in some of the results obtained during the period of study.

During the mode of operation of the disc cleaner with water recycle and chemical coagulation-flocculation, a series of jar tests were conducted to determine the optimum coagulant (Calgon Cat-Floc) concentration. In view of the daily variations in soil characteristics, jar tests were conducted for several days. Results indicated that the desired coagulant concentration ranged from 7 to 15 mg/l.

Difficulties were encountered in sampling during the latter part of the study period. The composite samplers were out of order, and, consequently, the grab sampling technique was used. Due to the sharp variations in solids concentrations it was difficult to collect representative grab samples. This made it difficult to evaluate the quality of water overflowed to the sewer.

Under conventional cleaning, the total soil solids which were loaded to the plant were estimated from the sum of soil solids accumulated in the dump tank and lost with overflow from the flumes to the sewer. The former was determined by the total volume and concentration of soil solids shoveled into the gondolas. The latter was determined by the total overflow volume and soil concentration to the sewer. For example, on September 4th there were a total of 11,779 lbs of soil solids to the plant. Of this, 7,384 lbs were estimated to be lost to the sewer while 4,395 lbs were shoveled out of the dump tank into gondolas. There were a total of 489 tons of tomatoes processed; the soil loading per unit of tomatoes was, for this particular day, 24 lbs/ton of tomatoes processed, or, slightly in excess of 1% of raw product weight.

Under the conventional mode with water recycle the total soil solids incoming to the plant were from three sources: soil solids removed from the dump tank, lost to the sewer, and removed from the thickener. For example, on September 10th there was a total of 5,451 lbs of soil to the plant. Of this, 1318 lbs were removed from the dump tank, 2,103 lbs were lost to the sewer, and 2,030 lbs were removed from the thickener. Since there was a total of 433 tons of tomatoes processed on this day, the unit soil loading per ton of tomatoes processed was 13 lbs/ton. Similar daily analyses were made on all data collected.

Average Soil Loadings--Table 6 presents the average total soil loadings and the unit loading rates under each mode of operation. As shown by the second column of Table 6, approximately 3,800 lbs/day of soil solids were removed from the dump tank in the conventional mode without recycle. This represents a unit soil loading of 7.9 lbs/ton of tomatoes processed. A significant decrease in soil solids removed from the dump tank was noted as the water recycle was implemented. For example, there were only 1,447, 1293 and 1244 lbs/day of soil solids removed from the dump tank for conventional with water recycle, disc cleaner with water recycle, and disc cleaner with water recycle and chemical coagulation-flocculation, respectively. The unit soil solids removed from the dump tank were 3.3, 2.2, and 2.1 lbs/ton respectively for these three modes of operation.

Data is presented in the fourth and fifth columns of Table 6 that indicates that there were 12.5 lbs of soil per ton of tomatoes processed lost to the sewer under conventional cleaning whereas there were 4.1, 1.3 and 0.9 lbs/ton lost to the sewer in modes with water recycle. This indicates that soil solids lost to the sewer decreased as water recycling was implemented.

Three point seven (3.7), 6.4, and 8.3 lbs of soil/ton of tomatoes processed were removed from the thickener in the conventional cleaning, disc cleaning, and disc cleaning with chemical flocculation modes, respectively. This indicates that the unit weight of soil solids removed from the thickener increases as more sophisticated removal measures such as chemical flocculation were implemented.

In the last column are presented the average soil solids loading per unit of tomatoes processed. Twenty, 11, 10, and 11 lbs of soil/ton of tomatoes processed were accounted for in the conventional, conventional with

TABLE 6

AVERAGE SOIL LOADINGS BY OPERATIONAL MODE

Mode of Operation	Total Tomato Processed (tons/day)	Soil Solids Removal From Dump Tank		Soil Solids Lost to Sewer		Soil Solids Removed From the Thickener		Total Soil Solids to the Plant (lbs/day)	Soil Per Unit of Tomato (lbs/ton)
		(lbs/day)	(lbs/ton)	(lbs/day)	(lbs/ton)	(lbs/day)	(lbs/ton)		
Conventional	481	3796	7.9	6029	12.5	--	--	9825	20
Conventional w/Recycle - w/o Floc.	445	1447	3.3	1807	4.1	1628	3.7	4882	11
Disc Cleaner w/Recycle - w/o Floc.	594	1293	2.2	747	1.3	3827	6.4	5867	10
Disc Cleaner w/Recycle - w/Floc.	605	1244	2.1	547	0.9	5038	8.3	6829	11

recycling, disc cleaner with recycling, and disc cleaner with recycling and chemical flocculation modes, respectively.

Several important conclusions can be drawn from the observations above:

1. The apparent plant capacity for tomato processing increased with disc cleaning and water recycle.

2. The soil solids removed from the dump tank per unit weight of tomatoes processed decreased significantly as water recycling was applied.

3. Soil loads to sewers per tonnage of tomatoes processed decreased as water recycling was implemented.

4. Soil solids removed from the thickener per unit weight of tomatoes processed increased as water recycling was applied.

5. Incoming soil solids per ton of tomatoes processed ranged from 10 to 20 lbs/ton, having an average of 13 lbs of soil per ton of tomatoes processed.

Distribution of Soil Loadings--An analysis of soil solids distribution under each operational mode is presented in Table 7. With conventional washing, 39% of the soil was accumulated in and removed from the dump tank. The balance of 61% was discharged to the sewer.

The percentage of soil solids discharged to the sewer sharply decreased as water recycling was implemented. In the conventional mode with water recycle, 37% of the soil solids were discharged to the sewer. For both modes of operations with the disc cleaner, the percentage of soil solids discharged to the sewer decreased substantially.

Soil solids accumulating in and removed from the dump tank were reduced significantly in modes of operation with recycle. The majority of the settleable soil solids were effectively intercepted and transported to the swirl concentrator. Only a small percentage of soil solids accumulated in the dump tank.

Economic Significance of Water Recycle With Soil Removal

An economic evaluation was made of a typical tomato processor discharging to a municipal sewer. Charges for this service are usually established by the municipal agency so that the operating cost of its facility are varied and distributed according to usage. However, this practice often may be unfavorable to the average tomato processor who operates on a seasonal basis.

TABLE 7

DISTRIBUTION OF SOIL LOADINGS BY OPERATIONAL MODE

Mode of Operation	Soil Solids From Dump Tank (%)	Soils Discharged Into Sewer (%)	Soil Removed by the Thickener (%)
Conventional	39	61	--
Conventional w/Recycle - w/o Floc.	30	37	33
Disc Cleaner w/Recycle - w/o Floc.	22	13	65
Disc Cleaner w/Recycle - w/Floc.	18	8	74

Cost-Effectiveness Evaluation

On Table 8 are listed the industrial wastewater charges for Sacramento County, California as proposed for 1978.(6) Total charge is the sum of five items: demand charges, loading charges, service charges, monitoring charges, and potable water use charges. To illustrate the economic significance of in-plant water recycle with soil removal for the tomato processor, an evaluation was made based on the parameter values obtained in this study as listed on Table 9.

The following assumptions are made:

1. Period of operation - 60 days.
2. Solid (sg 1.5) concentration of the mud from the dump tank - 60%.
3. Solid (sg 1.2) concentration of the sludge from thickener - 30%.
4. Total unit soil loading rate - 15 lbs/ton tomato processed.
5. Unit soil loadings (based on the average solid distribution as indicated in Table 6).

	Soil Solids Removed from Dump Tank (lbs/ton)	Soil Solids Removal From Thickener (lbs/ton)
Conventional	5.9	--
In-Plant Treatment	2.7	11.1

6. Solid hauling cost - $\$3.00/yd^3$
7. In-plant facilities cost - $40,000
   Useable life - 5 years, straight line depreciation
   Operational and maintenance cost - $20,000 annually for all systems.
8. Service - 2 miles - 8" diameter or 16 diameter inch miles.

The total estimated annual cost consists of the charges for discharging into the municipal sewer system, sludge hauling cost for hauling the collected solids to the disposal field, the annual capital cost for in-plant pre-treatment facilities and annual operational and maintenance cost. The industrial wastewater charges in Sacramento County by this typical tomato processing plant with and without in-plant treatment are compared in Table 10. The evaluation indicated that approximately $1.80/ton of tomatoes processed would be charged without water recycle and soil removal. Approximately $.30/ton of tomatoes processed would be charged if in-plant treatment were implemented.

TABLE 8

MONTHLY INDUSTRIAL WASTEWATER UNIT CHARGES SACRAMENTO COUNTY, 1978

1. Demand Charges	
Peak flow rate, per MGD	$ 1,069.00
Peak BOD_5 loading, per lb/day	0.39
Peak SS loading, per lb/day	0.10
2. Loading Charges	
Volume, per MG	85.25
BOD_5 per 1,000 lb	43.00
SS, per 1,000 lb	42.80
3. Service charge for handling the flow, per diameter inch mile	17.00
4. Monitoring charge, per month	126.75
5. Potable water use charge, per 1,000 ft^3	0.85*

*$123 for the first 1,000 ft^3/month

TABLE 9

AVERAGE TOMATO PROCESSING PLANT WASTEWATER PARAMETERS (BASED ON '75 SEASON STUDY)

Parameter	Conventional System	In-Plant Treatment and Conservation Systems
1. Average Unit Water Use Rate (gal/ton)	280	160
2. Average Daily Tomatoes Processed During Processing Season (ton/day)	480	600
3. Average Daily (Peak Monthly) Wastewater Flow Rate During Processing Season. (gal/day)	140,000	90,000
4. Peak Daily Tomatoes Processed During Processing Season. (ton/day)	520	670
5. Estimated Peak Daily Wastewater Flow Rate During Processing Season. (gal/day)	155,000	100,000
6. Estimated Average Suspended Solids (SS) Concentration of Wastewater. (mg/l)	8,000	800
7. Average Chemical Oxygen Demand (COD) of Wastewater (mg/l)	2,750	2,900
8. Estimated Average 5-Day Biochemical Oxygen Demand of Wastewater (mg/l)	1,100	1,000

TABLE 10

ESTIMATED ANNUAL MUNICIPAL CHARGES TOMATO PROCESSING WITH AND WITHOUT IN-PLANT TREATMENT

Charge Basis	Estimated Average Unit Costs for a Conventional System ($/ton)	Estimated Average Unit Costs for an In-Plant Treatment System ($/ton)
1. Demand Charges Based On:		
Peak Flow Rate	$ 0.07	$ 0.03
Peak BOD's Loading	0.73	0.11
Peak SS Loading	0.43	0.02
2. Loading Charges Based On:		
Total Flow	0.02	0.01
Total BOD's Loading	0.12	0.05
Total SS Loading	0.83	0.04
3. Services Charges	0.02	0.02
4. Monitoring Charges	0.01	0.01
5. Potable Water Use Charges	0.03	0.02
Estimated Total Annual Municipal Charges	$ 1.76	$ 0.31

On Table 11 are compared the total annual costs with and without in-plant pre-treatment. While both costs in sludge hauling and in-plant O&M increase, due to the saving in the municipal charges, the total annual unit cost savings is estimated to be approximately $1.31/ton of tomatoes processed with in-plant treatment. An estimated 53% savings would be realized through use of the in-plant treatment system demonstrating that in-plant treatment is a cost-effective approach.

REFERENCES

1. Bin Dump Tank Grit Collection and Transport System Model Study, EUTEK, Report prepared for NCA, June 1975.
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3. Cleaning and Lye Peeling of Tomatoes Using Rotating Rubber Discs, Western Regional Research Center, USDA and National Canners Association, April 1974.
4. Flocculation Apparatus, U.S. Patent No. 3,933,642, January 20, 1976.
5. Liquid Wastes from Canning and Freezing Fruits annd Vegetables, EPA 12060 EDK, August, 1971.
6. Industrial Unit Charge Rates in Sacramento County, CA, Division of Water Quality, Department of Public Works, County of Sacramento.

TABLE 11

COMPARISON OF TOTAL ANNUAL WATER RELATED COSTS WITH AND WITHOUT IN-PLANT WATER CONSERVATION SYSTEMS

	Municipal Charges ($/ton)	Sludge Hauling Cost ($/ton)	Annual Capital and Operation and Maintenance Cost ($/ton)	Total Annual Cost ($/ton)
Conventional System	1.76	0.01	0.19	2.46
With In-Plant Water Conservation System	0.31	0.06	0.78	1.15

Potential Net Annual Savings = (2.46 - 1.15)(60)(600) = 47,160

PROTOTYPE APPLICATION OF SINGLE PARAMETER SLUDGE AGE CONTROL TECHNOLOGY - A CASE HISTORY - PERFORMANCE OPTIMIZATION BY APPLICATION OF SLUDGE AGE CONTROL TO EXTENDED AERATION TYPE TREATMENT PLANT FOR FOOD PROCESS WASTES**

by

Calvin G. Brown, P.E.*

INTRODUCTION

"The Lord by wisdom hath founded the earth; by understanding hath he established the heavens."(1)

"Happy is the man that findeth wisdom, and the man that getteth understanding.

For the merchandise of it is better than the merchandise of silver, and the gain thereof than fine gold.

She is more precious than rubies and all the things you canst desire are not to be compared unto her."(2)

Because we have entered a new era of biological treatment kinetics, or bio-kinetics understanding, let me briefly review well known recent history pertinent to this paper's topic.

For decades, especially since 1914, when the activated sludge process was first applied to wastewater treatment, engineers and scientists have been seeking greater understanding of nature's process of stabilizing sewage and other man-made wastes.

Lacking this vital understanding, operational data from many operating plants was reviewed and used to develop empirical rationale, which were then incorporated in the Ten States Standards (3). This procedure has resulted in the perpetuation of very conservative design criteria use, modified by trial and error, which today is still basically the State-of-the-Art. The net result, however, has been very little increase in the ability of designers to control or accurately predict effluent quality of activated sludge systems.

Credit for the first major breakthrough in focusing attention on a measurable parameter affecting effluent quality belongs to Garret in 1958 (4). This was in regard to the hydraulic control of the sludge soluble rate.

In the mid 1960's, the U.S. Congress and N.Y.S. Legislature passed historic water quality control legislation with grant-in-aid funding, and the flood of research on treatment processes began.

In 1968 Jenkins and Garrison published their treatise on "Control of Activated Sludge by Mean Cell Residence Time" (5).

At the same time Professor A. W. Lawrence of Cornell University, in collaboration with Professor McCarty, was developing and proving his unique theory that optimal design and control of activated sludge was practical utilizing only the single parameter, sludge age. Their paper, published at Cornell University in 1969, was based on extensive laboratory experiments (6).

A paper on control of solids retention time (SRT) was presented by Walker in 1971 (7).

In late 1971 the author's firm was engaged to design a 24 MGD tertiary treatment plant (8) requiring nitrification. Prof. Lawrence was retained to determine whether one stage or two stage nitrification was required for the domestic waste, utilizing sludge age control, in the vigorous Western N.Y. climate. The results were presented in January 1973 (9) and excerpts appear in EPA's new Nitrogen Control Manual (10).

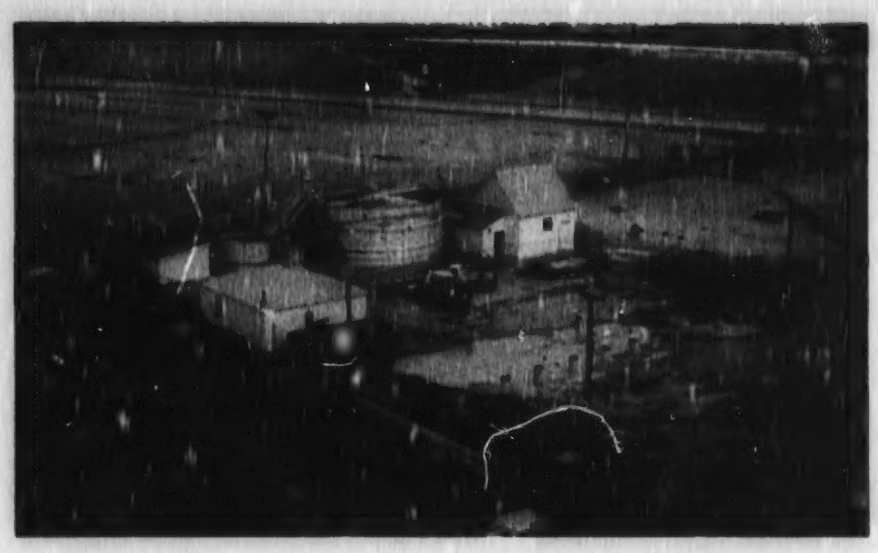
As explained later in more detail, the work of R. I. Dick published in 1970 (11) on final settling tanks has proven invaluable in providing the final element required to fully implement sludge age control on a practical and economical basis. The entire activated sludge process facilities design and operation can now be properly implemented with confidence.

In 1973, the NYSDEC review staff advised our firm that our proposed sludge age control technology, although showing promise, could not be approved, since operational data of the "process" was not available in the United States. At the same time, EPA's Region II R&D Screening Committee labeled our findings (9) as the major breakthrough in advancement of bacteriological treatment in 30 years. Metcalf & Eddy's new Wastewater Treatment Textbook (12) also contained extensive detail on sludge age kinetics.

PROJECT SCOPE

The opportunity to apply the single control parameter of sludge age to an existing conventional activated sludge type plant came in September 1974. Our firm was retained then for studies of and preparation of a report on required modifications to Company X's Waste Treatment Plant in Western New York, built in 1968. Company X produces over 100 tons of frozen dinners a day, with over 500 employees. See Figures No. 2 and 3, which are: 2. Photo of Waste Treatment Plant; 3. Schematic of Process Flow Existing. (Figure 1 not used).

The company's NPDES permit, issued in July 1974, dictated the scope of studies and reports described in this paper by establishing final effluent parameter limits.



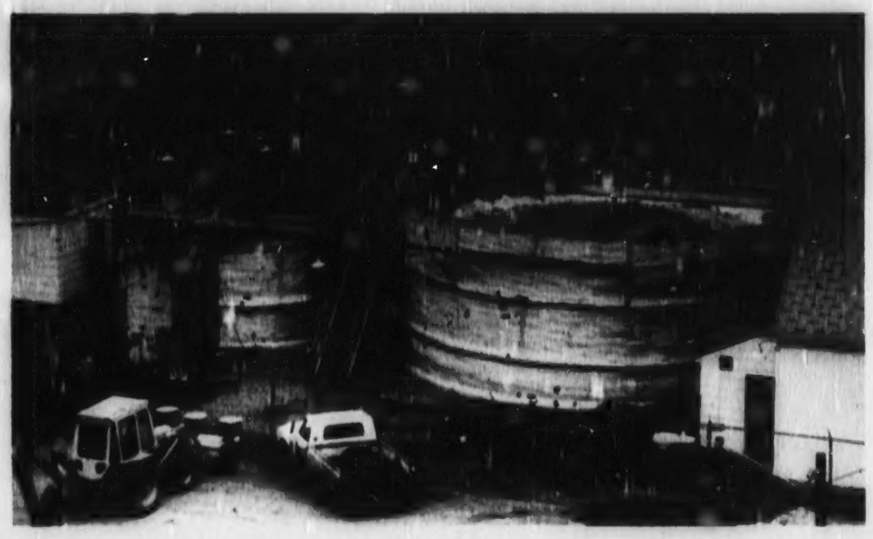


Figure 2. **EXISTING WASTE TREATMENT PLANT (BUILT 1968)**

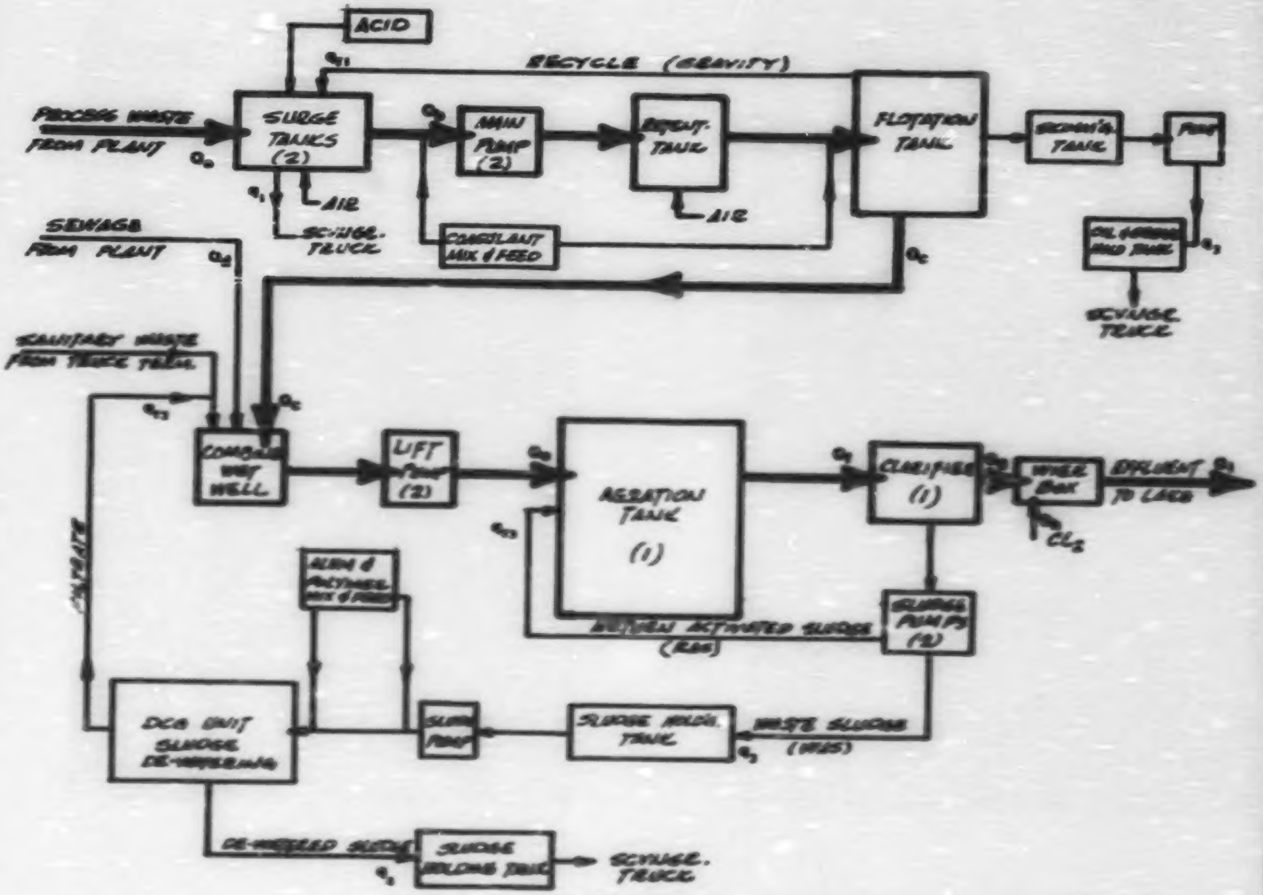

ACID
RECYCLE (GRAVITY)
PROCESS WASTE FROM PLANT
Q_0
SURGE TANKS (2)
Q_{11}
Q_1
AIR
SCVNGR. TRUCK
Q_2
MAIN PUMP (2)
RETENT. TANK
AIR
COAGULANT MIX & FEED
FLOTATION TANK
SKIMMING TANK
PUMP
OIL GARBAGE HOLD TANK
Q_3
SCVNGR. TRUCK
Q_c
SEWAGE FROM PLANT
Q_d
SANITARY WASTE FROM TRUCK TERM.
Q_{13}
Q_c
COMBINED WET WELL
LIFT PUMP (2)
Q_8
Q_{10}
AERATION TANK (1)
Q_7
CLARIFIER (1)
WEIR BOX
Cl_2
EFFLUENT TO LAKE
FILTRATE
ALUM & POLYMER MIX & FEED
SLUDGE PUMPS (2)
RETURN ACTIVATED SLUDGE (RAS)
DCG UNIT SLUDGE DE-WATERING
SLUDGE PUMP
SLUDGE HOLD. TANK
Q_5
WASTE SLUDGE (WAS)
DE-WATERED SLUDGE
Q_6
SLUDGE HOLDING TANK
SCVNGR. TRUCK

Figure 3. **EXISTING WASTE TREATMENT FACILITY**

The pertinent NPDES final effluent limitations (effective 2/1/76) are:

Parameter	Discharge Limitation #/D	
	Ave. Day	Max. Day
BOD_5	23	46
TSS	32	64
Cr_T	0.2	0.4
Zn_T	--	0.4
pH	6.5 min	8.5 max
Fecal Coliform	200 (MPN/100ml/ 30 day)	400(MPN/100ml/ 30 day)
Temp		Not > 90°F

This paper describes the successful prototype application of sludge age control to operation modifications of a conventional plant and to design considerations for an extremely restrictive effluent quality requirement.

In order to understand the data and changes in operation, the study sequence of events was as follows:

	DATE
Permit Issued	7/31/74
Engineers Retained	9/4/74
Report on 7 Day Monitoring Report - Schedule I	9/30/74
Start Routine Operations Sampling - Schedule II	10/1/74
Complete Report on Evaluation of Existing Facility and Modifications Design - Based on 7 Day Monitoring Data	1/31/75
Start 34 Day Test Period per Design Report Recommendations	4/14/75
Complete 34 Day Tests	7/3/75
Complete 7 Day Air Flotation Unit Tests	9/9/75

Complete Addendum A: Revised Design Report, Based on 34 Day Test Results	1/14/76
Begin Preparation of Final Plans & Specs Based on Addendum A	2/16/76

FROZEN FOODS PROCESSED

In order to properly evaluate the company's waste, it was necessary to review the products processed and the probable variation in waste characteristics. A typical week's production categories are given in the following tabulation. These consisted generally of 30% sliced, 60% fried and 10% fruit and other products.

TABULATION - FROZEN FOODS PROCESSED

	Day of Week					
Product	Mon 9/23	Tues 9/24	Wed 9/25	Thur 9/26	Fri 9/27	Sat* 9/28
Char Broil Beef Patty	X	X	X	X		
Gravy & Sliced Beef	X	X	X		X	
Gravy & Sliced Turkey	X			X	X	X
Gravy & Sliced Chicken			X			
Meatloaf	X			X	X	X
Salisbury Steak	X	X	X	X		X
Veal Parmagian		X				
Chicken Croquette						
Man Size Beef Patty				X		
Turkey Croquette					X	
Fruit Cocktail		X	X			
Orange Jello	X			X	X	X
Diced Peaches		X				
Strawberry Fruit			X	X	X	X
Applesauce	X					
Sliced Turkey			X			
Fried Chicken			X			
Fish				X		
Spaghetti				X		
Chicken Ala King	X					
Gravy & Beef		X			X	
Gravy & Turkey	X					

*Saturday not a regular scheduled working day.

The principal process sequences are mixing and slicing (flour & spices), meat preparation & packing, oil cooking, breading, gravy and noodles cooking, school lunch mini-pak and lunch room.

Since there is a single final discharge point waste stream, it was not necessary to evaluate subprocess streams. A complete typical description is available in EPA Wastewater Characterization for the Specialty Food Industry, Category 1. (13)

WASTEWATER CHARACTERISTICS AND ANALYTICAL PROCEDURES

The most important rules a designer must observe in establishing waste characteristics for a process waste are

(1) Secure representative data over a statistically valid period of time.

(2) Calibrate all flow measurement devices and check sampling and analytical techniques.

(3) Determine correlation between processing operations and waste generated.

(4) Utilize an independent laboratory certified by EPA for intensive testing, preferably having the same technician and approved technique involved in all analysis during the tests.

The effects of departing from these rules are quite well illustrated in this project.

The NPDES permit required an immediate monitoring of waste characterization over a 7 day period. Company officials requested that this test data be used to provide the basis for a complete report on modifications to the W.T.P. in order to comply with the NPDES compliance schedule. We were to implement sludge age control as much as possible for this test period.

This was accomplished, with our accompanying recommendation, however, that sludge age control be fully applied to W.T.P. operations and that a minimum of 30 days test data be acquired. This would provide a statistically accurate basis for designing a lower first cost and operating cost treatment system, we stated.

The following Tables illustrate the comparison between the original design loading criteria, the 7 Day monitoring data and the actual 34 Day test data waste loadings to the W.T.P. All tests were made in accordance with Standard Methods for the Examination of Water and Wastewaters, 13th Edition, 1971, APHA NYNY.

All sampling, but only solids analyses, were performed by company personnel. All other sampling analyses were performed by Ecology and Environment Inc. laboratory, Cheektowaga, N.Y. under the general direction of Gerald L. Stobel, P.E. and direct supervision of Rocco Termini.

It is to be noted that the 7 Day data indicates that the loading to the W.T.P. aeration tank is greater than the raw waste load of BOD_5 to the W.T.P., whereas for the 34 Day average aeration tank loading is about 2/3 of the raw waste BOD_5 content.

In the discussion on plant operation, the reasons for this anomaly will become evident.

The processing plant's production vs water use is listed in Table No. 1 and 1A.

The characteristics of the raw waste and the aerator applied loadings are in Table No. 2 and 3, while aerator-clarifier operating data is listed in Table No. 4.

TABLE 1. PRODUCTION VS WATER USE AND WASTEWATER FLOW - 7 DAY TEST

Day	Production Tons/Day	Water Used Gals.	Water Use Gals/Ton	Process Wastewater Flow Gals.	Process Wastewater Flow Gals/Ton
Mon 9/23	153.0*	101,690	665	84,800*	555
Tues 9/24	123.6	105,300	850	64,280	520
Wed 9/25	128.3	102,330	800	62,730	489
Thur 9/26	112.7	102,810	910	57,990	515
Fri 9/27	110.1	104,990	950	51,900	470
Sat	89.2	86,100	965	52,260	585
		6 Day Data Averages			
Min	89.2	86,100	665	51,900	470
Ave	119.5	100,550	840	62,000	522

TABLE 1. (CONT.)

Day	Production Tons/Day	Water Used Gals.	Water Use Gals/Ton	Process Wastewater Flow Gals.	Process Wastewater Flow Gals/Ton
			6 Day Data Averages (Cont.)		
Max	153.0*	105,360	965	84,800*	585
			Data as Percentage of Averages		
Min	74.6	85.6	79.2	83.7	90.0
Ave	100.0	100.0	100.0	100.0	100.0
Max	128.0*	104.8	114.9	136.7*	112.1

*Maximum Data

Note: Data reported on 9:00 AM to 9:00 AM; while each day's shift start-up was 6:00 AM and production started at 7:00 AM. Thus there is a lag between water use and waste generated recorded for each day of the test period. Previous flows were reported from midnight to midnight.

Table 1A. BASE DATA - 34 DAY TEST PERIOD APRIL & JUNE 1975

PRODUCTION AND FLOW (including D.C.G. Filtrate Inflow)

Date	Production (Tons/Day)	WASTE FLOW: W.T.P. Aeration Tank Inflow (incl sewage) (Galsx1000)	Date	Production (Tons/Day)	WASTE FLOW: W.T.P. Aeration Tank Inflow (incl sewage) (Galsx1000)
	Conversion Period			Sludge Control Period	
Apr 14	126.4	36.5	Jun 9	136.1	65.6
15	127.2	50.9	10	130.8	70.9
16	128.7	63.2	11	138.9	56.6
17	135.0	47.2	12	140.5	68.9
18	118.7	45.0	13	121.8	47.1
Apr 21	118.5	44.7	Jun 16	150.5	42.6
22	129.9	74.2	17	126.6	69.2
23	123.0	72.7	18	139.0	63.3
24	136.1	70.6	19	146.5	56.0
25	117.4	37.7	20	118.8	45.6
Apr 28	138.6	72.3	Jun 23	129.5	54.7
29	126.6	57.8	24	145.0	48.6
30	144.9	36.3	25	140.1	60.4
May 1	135.8	33.5	26	145.7	54.3
2	135.4	47.8	27	134.1	44.9
			Jun 30	134.9	44.1
			Jul 1	135.0	44.9
			2	139.5	53.6
			3	141.5	39.8
	n= 15 $\bar{x}$=129.5 s= 8.1	n=15 $\bar{x}$=52.7 s=14.7		n= 19 $\bar{x}$=136.6 s= 8.3	n=19 $\bar{x}$=54.3 s= 9.9

Combined Data

Production (Tons/Day)	WASTE FLOW (Galsx1000)
n= 34 $\bar{x}$=133.4 s= 8.9	n=34 $\bar{x}$=53.6 s=12.0

Table 2. Unscreened Raw Waste Characteristics

Parameter			7 Day Test (1974)		34 Day Test (1975)	
Flow Q (gpd)			Ave	62,000	49,000	
			Max	85,000	69,000	
				#/D	mg/l	#/D
BOD_5	Ave			1400	2480	1000
	Max			1580	4010	2300
BOD_5/COD, Ave			.55		.55	
TSS	Ave			1440	3470	1400
	Max			2000	7240	4150
Oil & Grease (Ether Soluble)		Ave		320	1710	690
		Max		690	2800	1600
Cr_T	Ave			.04	--	--
Zn_T	Ave			.53	--	--
pH	Ave		4.7-8.7		6.5-8.6	
	Min-Max		4.7-12.4		- -	
Temp °C		Ave	11.7		21.5	
		Min	5.2		16.7	
		Max	16.3		24.0	

Table 3. Aerator Influent Waste Characteristics

Parameter		1968 Design		7 Day Test(1974)		34 Day Test(1975)	
Flow, Q(gpd)	Ave	100,000		62,000		53,500	
	Max	---		85,000		77,500	
		mg/l	#/D	mg/l	#/D	mg/l	#/D
BOD_5	Ave	825	687	3010	1500	1490	660
	Max			--	2420	1670	1020
COD	Ave	920	766	--	2800	2800	1250
BOD_5/COD	Ave	.90		.53		.53	BODult/
	Max			.47		.49	BOD_5=1.33
TSS	Ave	294	245	2450	1220	1690	750
	Max	---	---	--	2240	2440	1820
Oil & Grease	Ave	0	0	370	185	400	180*
	Max	-	-	--	410	600	360*
						(*calculated from COD)	
pH	Ave	6.7		4.1-6.7		4.8-8.5	
Temp °C	Ave	21°		12.3		20.0	
	Min	--		4.2		10.1	
	Max	--		19.8		27.8	

Table 4. **Aerator - Clarifier Operating Data**

Parameter		1968 Design	7 Day Test(1974)	34 Day Test(1975)
BOD_5#/KCF	Ave	52	113	50
	Max	--	181	77
MLSS mg/1	Ave	--	10,700	7,100
	Max	10,000	13,800	10,800
MLVSS/MLSS		--	.80	.66
Detention Time, hrs. (Hydr)		20.4	33	38.2
F/M #BOD_5/#MLVSS		--	.26 (.43max)	.13 (.29max)
Clarifier Loading TSS#/sf/d		--	28.6 (41max)	25.7 (46.5max)
Sludge Age-days (SRT) (Calculated)			57 (4 min - 208 max)	8.3 (3.0 min - 9.6 max)
RAS recycle % Q		25	100 (50 min - 170 max)	250 (130 min - 380 max)
Metals Conc. (Aerator)				
Cr mg/1			0.12	Not measured
Zn mg/1			2.6	
Fe mg/1			12.2	"
Cu mg/1			0.4	"

EXISTING TREATMENT PLANT FACILITIES

The existing treatment facilities were sized and operated up through 1974 in accordance with conventional design (Ten States Standards). Operators were trained in state sponsored sewage treatment plant operator schools. They found very little practical application to this process waste treatment operation was possible.

It should be noted that the area in which Food Company X is located, is not served by city sewers nor interceptors.

A brief explanation of the facilities and operation in September 1974 is as follows. These include many improvements in facilities and operation initiated by company officials since 1968, and some at the suggestion of county officials.

The daily waste characterizations for all test periods are illustrated in Figure 4. Typical daily flow variation data is shown in Figure 5.

The unscreened process waste flows under pressure into two surge tanks which hold about two thirds of an average day's flow. Bottom air diffusers aid in breaking up emulsifying grease and solids and minimize odors. pH can be adjusted by chemicals in the surge tank. Solids and emulsified grease settled in the bottom two feet and were pumped by scavenger several times a week.

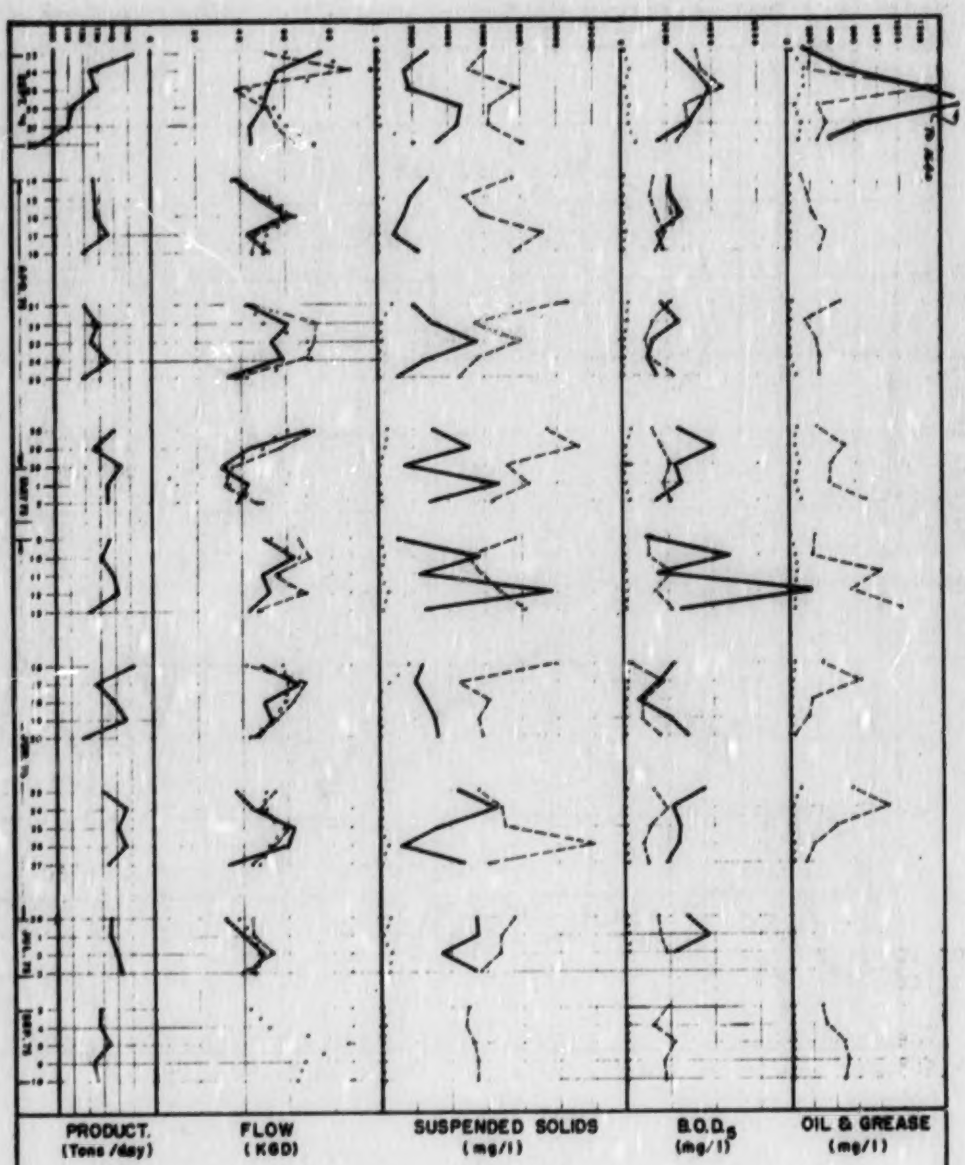
Oversized trash pumps lifted the waste to an air flotation system at 20-30 psia. This system was inadequate to produce or maintain a float and about 10% oil and grease removals were effected during both test periods. In October 1975, use of a large air compressor and rearrangement of the trash pumps in series provided a 60 psia discharge head capability and resulted in increased oil and grease and solids removals. Alum and polymer are normally added.

The Air Flotation Tank weir discharge was mixed with unscreened domestic sewage in an intermediate wet well, together with the dewatered solids filtrate from the D.C.G. unit, and lifted by oversized centrifugal pumps to the aeration tank. Excess flow to the flotation unit was recycled via gravity pipe to the surge tanks up to 100% recycle.

The influent to the aeration tank was discharged onto the aeration tank surface alongside the clarifier RAS recycled flow at a point opposite the aerator overflow to the clarifier.

The aerator is a Lightnin Mixer 30 HP rated at 3.2# O_2/HP/hr., with surface aerator and submerged blade, providing complete mixing in a Suburbia aerator-clarifier system.

The aerator mixed liquor overflows to the clarifier, which had a nominal 250 gpsfd rating at design flow of 100,000 gpd, and 8'-4"SWD. A sludge draw off box with telescopic valve and oversized submerged sludge pump provided RAS recycle and WAS by manual valving.



WASTE CHARACTERIZATION DATA:
PRINCIPAL PARAMETERS, from
Sept. 74 - Sept.75 Test Periods

Figure 4.

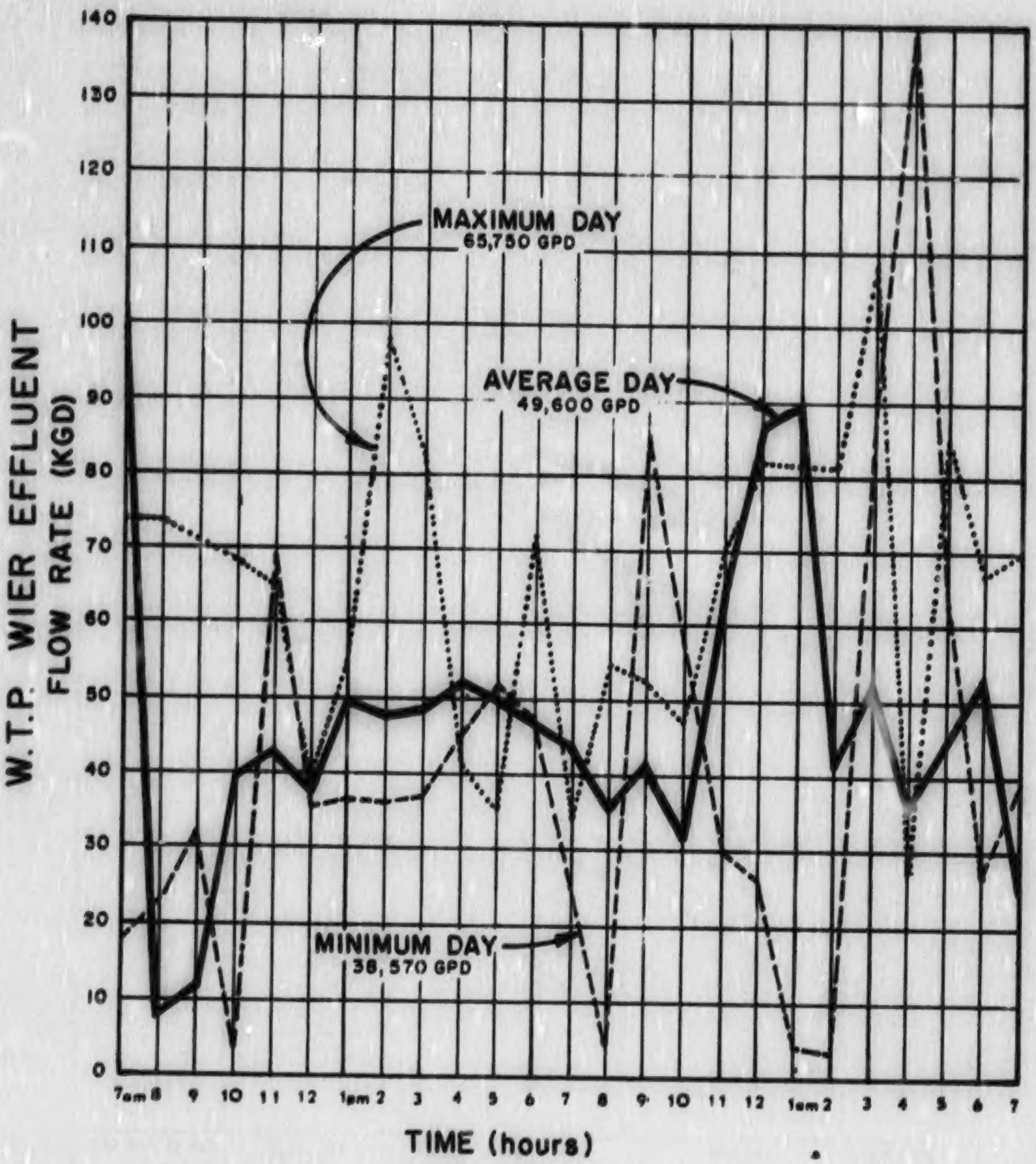


Figure 5.

TYPICAL DAILY FLOW FLUCTUATIONS

(34 Test Day Period - 1975)

The clarified effluent flowed through a chamber with less than 5 minute detention, where Cl_2 is diffused into the flow. A 60°V notch weir at the end of the chamber provided flow level for a BIF float operated recorded, transmitter and recorder measurement system.

The effluent flows to Lake Erie above the lake high water level via a 12" diameter outfall.

The plant is located at the east end of Lake Erie and is subjected to 50-75 mph winter gales and is subject to infrequent surface water flooding.

Because of high water table and poor subsoils, the plant is wholly at or above ground level.

The initial plant was as described but without any surge tanks, polymer mixing tanks, submerged aerator blade, DCG (dual cell gravity solids thickener) for WAS processing, laboratory, or flotation recycle pipe to surge tanks.

Over the years, company officials found that equalization was required; that polymers aided in securing better grease float; that a submerged aerator blade prevented anaerobic sludge build-up on the tank bottom; and the DCG unit resulted in less volume of sludge for scavenger trucking to landfill. The flotation recycle pipe reduced flow variation somewhat and smoothed loading to the flotation unit.

EXISTING TREATMENT PLANT OPERATION

In this paper, only those operating features will be discussed which are related and significant to our discussion of sludge age control vs conventional control. There are of course certain procedures which are equally applicable to improving any plant operation. In order to compare the two control methods the "before" and "after" operating conditions will be summarized in this section and detailed operation will be described in later sections.

The plant operator has a New York State Sewage Treatment Operator's license and has taken the prescribed two week course. One shift operator had taken the two week course in 1975. The other shift operators are scheduled to take the course in the near future.

In 1974 one operator was on duty each 8 hour shift on plant production days.

Daily settled 24 hour composites were analyzed for BOD_5 and solids, pH, temperature and Cl_2 residual, of raw, effluent and aerator mixed liquor. Monthly reports of BOD_5, TSS and S.S. were based on Thursday's averages for 1974. Prior to September 1974, scavenger pumping of surge tanks and WAS storage tanks, at about 50% of weir flow, kept the loading to the aeration tank at reasonable levels. Thus the plant appeared to provide about 90% removals of BOD_5 and T.S.S.

Cl_2 residual of 0.5 mg/l was carefully maintained at the weir effluent (not at the outfall discharge at Lake Erie).

Scheduled tests were supposed to be run every shift (3/day) on the following parameters at six locations 1) surge tank, 2) flotation unit, 3) intermediate wet well, 4) aeration tank contents, 5) clarifier blanket, 6) weir effluent

a) TS, TVS, TFS
b) TSS, VSS
c) S.S.
d) DO
e) BOD_5
f) Oil & Grease (occasionally)
g) pH
h) SVI
i) Cl_2 residual

The basic control of operation up through 1974 has been to use scavenger service to pump out surge tanks, oil & grease holding tank, waste sludge tank, and even clarifier if solids discharge to Lake Erie became excessive so as to be visually detectable by adjoining property owners and regulatory agencies.

At $45 per 1000 gallons in 1974 and 1975, for scavenger service collection and disposal at remote sanitary landfill, the cost was excessive even to maintain normal secondary removal efficiencies. This equalled weekly costs of $1400 to $1800. In 1976, the cost increased to $70 per 1000 gallons for this service.

The chief operator has been most aggressive in seeking out information from trades people, other operators and industry sources, and self study on how to improve operation and effluent efficiencies.

Our evaluation indicatedd, however, that interaction of existing facilities and their non-complimentary capabilities provided major hindrances to more effective operation.

For instance, in order to decrease solids overflow in plant effluent by excessively wasting activated sludge from the clarifier, the BOD_5 removal efficiency decreased, as there were insufficient bacteria left in the aerator for effective metabolism.

The following comparison between the major operational conditions is given here as the discussion of the test period results are related to these facts. Parameter data is in Tables No. 1 through 5.

The most significant cost savings resulting from sludge age control was due to the large decrease in waste activated sludge volume and the reduction of raw waste scavenging.

OPERATING CONDITIONS
(with no capital cost revisions to facilities)

	"Before" (w/Conventional Operation)	"After" (w/Sludge Age Control Operation)
1.	WAS conc to DCG=1-2%	WAS Conc to CDG 2-3%
2.	WAS conc from DCG=3-5%	WAS Conc from DCG 6-15%
3.	Total Volume raw waste, grease & oil, & WAS TO Scavenger=36,000-38,000 g/p/wk	Total Volume raw waste, grease & oil & WAS to Scavenger=27,000 g/p/wk
4.	@$70/1000 gal annual scavenger cost equals $138,000	@$70/1000 gal annual scavenger cost equals $98,000; scavenger = $40,000/yr. savings
5.	RAS recycle rate 10-25% (actual rate due to incorrect flow data was 20%-50%)	RAS recycle rate ranged from 100%-400%
6.	Grease emulsion formed daily in surge tank bottoms requiring bi-weekly scavenger pumping	Grease emulsion pumped out infrequently once or twice a month-balance handled by aeration thru longer sludge age
7.	Excessive flow variations resulted in frequent spillovers of wastewaters to the parking lot adjacent to W.T.P.	Infrequent spillovers; during test periods - none occurred.
8.	Air diffusers in surge tank plug up-level indicators fail and pumps clog up from oil, grease, debris solids plugging small valves and lines.	Regular maintenance on more frequent basis greatly reduced down time and reduced frequency of downtimes.
9.	Trash pumps in parallel: air bound pump empty at times. Pumping at 32-35 psi close to shut off head-cavitation pronounced. Hardly any grease float.	Pumps in series pumping at 53-60 psi total: better performance of pumps and air flotation system (This was operation improvement)
10.	Wet well lift pumps to aerator clog from sewage debris-float controls jammed frequently. Pumps on-off 5-15 seconds due to	Pumps throttled to permit 5-15 minute cycle on-off. Sewage debris cleanout more often. (This was operation improvement)

	oversizing and small wet well level variation available.	
11.	Very little floc forms on water surface of flotation tank.	3-6" float forms on water surface of flotation tank. Larger air compressor used.
12.	Chemical pumps clogged.	Same
13.	No effluent discharge from flotation tank at times.	More uniform discharge.
14.	No D.O. residual in aeration tank-30 HP operated 24 hr/day during production days.	5 mg/l to saturation D.O. measured in aerator tank at all times, 30 HP shut off at times.
15.	Reading on influent pH (adjustment in surge tanks) S.S., and aerator D.O. required hourly to provide some control on processes to prevent bulking sludge and poor effluent.	No readings for control purposes needed of influent pH and S.S. and aerator D.O.
16.	Aeration unit foaming frequent.	Infrequent
17.	Aeration unit short circuiting	Lower average flow rates to aeration unit reduced short circuiting.
18.	MLSS variation unmanageable at times, if too high overloaded clarifier, pumping by scavenger from clarifier only control available.	Increasing recycle rate controlled most MLSS variations
19.	Either too little air apparently; or too much air if low BOD loading to W.T.P.	No problem with minimum or maximum air supply.
20.	Sheared Floc aeration unit affected settling characteristics of MLSS.	No change - when reduced speed of aerator is installed, improvement is anticipated.
21.	Septic sewage in existing wet well.	None
22.	Difficulty in returning sludge at low recycle rates or at very high rates.	By throttling valves, and recycling in 20-30 minute periods, instead of very short or continuous recycling, permitted good control.

It is of greatest interest to note that most of the reported operating problems for conventional activated sludge systems occurred in this plant operation. Nearly all of these "ills" were reduced, brought under control. or eliminated merely by applying sludge control technology principles, without modifying existing facilities (except for a larger air source for the flotation unit).

FIRST TEST PERIOD - SEPTEMBER 1974 (7 DAY)

In order to comply with the NPDES Permit Compliance Schedule, Company officials directed our firm to develop the Seven (7) Day monitoring data and submit it by September 30, 1974 and use that data as the basis of designing necessary modifications. The engineering report was due January 31, 1975.

Our firm was commissioned to start on September 4, 1974. In our proposal to perform the work, a minimum 30 day test was recommended, however, before we could start testing all the unit operating facilities, especially the flow measuring systems, were routinely checked or calibrated.

A 100% error in reported Weir Effluent Flow was discovered, as was a similar variance in metered manufacturing plant waster use. After determining this, we set up a pumping recording charge. The 7 day monitoring was commenced on September 23, 1974. Weir flow head was measured hourly and calculated flow rate compared to recording equipment.

Several operating procedures were revised prior to the 7 day period. The aim was to begin instituting sludge control if possible for this test, even though in order to attain a true 8 day sludge age, for example, a 16 day operation is required before data is valid.

a) The recycling of flotation tank effluent to surge tanks was increased to reduce existing severe fluctuations of flow to the aeration tank.

b) Lift pumps to aerator were throttled to increase 5-15 sec. on-off cycles to -- 15 minute cycles minimum.

c) Recycle of RAS was increased fromm 25% to a minimum of 100% to minimize clarifier solids overflow. Attempts were made to utilize the equalization capacity of the surge tanks, but the plant was so grossly overloaded that this was not possible for the one week test.

d) Operators were requested to keep maximum forward flow from surge tanks under 70 gpm. (we found average flow was 35-50 gpm, not 70 gpm, as the recorder was incorrect as noted above).

e) Wasting of solids was reduced as much as possible in order to increase sludge age. When clarifier evidenced failure, wasting was allowed until effluent solids were reduced to acceptable levels.

f) Split composite samples over 24 hours were taken from six locations (previously described) at one hour intervals Monday through Saturday. Solids were analyzed by the plant operators, and all other parameters were analyzed by Ecology & Environment, Inc., laboratory.

g) Previous reported data was suspect; the kinetics of the waste were unknown; the process units maximum actual capabilities were unknown; the Weir at the chlorine chamber was the only flow measuring point; and operation control of the plant by the operators was primarily based on visual observation and operational knowledge acquired over years of experience.

h) The plant was severely overloaded during this first test week and no raw waste was removed from the raw process stream, as was done otherwise. All acquired flow data was by improvised methods instituted by our firm.

i) In comparison to 1968 design criteria, the plant was overloaded by two (2) times the BOD_5 design loading, and six to eight times the suspended solids design loading, on a weight basis.

j) The 7 Day monitored plant operation resulted in a hybrid combination of partial sludge control technique and previous hydraulic control practices, which were resorted to by operators whenever the effluent solids content indicated clarifier failure had occurred.

Although additional manpower was added for the test period (one man per shift), the lack of measuring and recording information, and lack of hourly information on influent loadings and flows, made it impossible to exercise adequate control by implementing frequency for required changes in flow rates, recycle rates, flotation tank pressures, pump throttling, sludge wasting, and the like.

The 7 Day results were analyzed and evaluated insofar as possible (statistical evaluation was not possible due to lack of sufficient occurrences, and correlation of data was nonexistent).

Tables 1 through 5 and Figures 4, 5, and 13 contain pertinent data from the September 1974 monitoring period.

Some of the more pertinent findings of this test were as follows:

a) The surge tanks were not used as equalization, but as storage, as the surface aerator being oversized 100% (determined later) appeared to overaerate. Over mixing of the waste on weekends resulted in a low MLVSS on Monday morning and thus too small a bacteria population to handle the organic loading beginning Monday morning. Thus the raw waste had to be fed slowly to the aerator to build up MLVSS.

b) The air flotation system operated at about 1/2 the desired air pressure due to the pump shutoff head restriction, and was furnished about 10% of the air required. Therefore its efficiency was about 5-10% and the aerator and clarifier contained what is reported to be excessive oil and grease for efficient metabolism. At short sludge ages, grease and oils were not effectively degraded, but at longer sludge ages much improved degradation was noted.

c) The aeration tank measured 0 mg/l dissolved oxygen (D.O.) when checked several times each day at 1/2 depth. A profile showed that 2-3 mg/l D.O. was maintained at 1-2 feet depths, but at 6 foot or greater, the D.O. was 0 to 1.0 mg/l. This was believed to be due to the high oxygen uptake of the waste. Later tests showed that the short sludge ages, high sludge yield (synthesis) and recorded MLVSS content caused this condition to exist.

The aerator influent pH was not effectively neutralized to an acceptable range by the oxygen available in the aerator.

d) Highly variable rates of forward flow which also exceeded the design hydraulic capacity appeared to result in excessive clarifier solids overflow to weir discharge, with proportional total BOD_5 in the effluent. Effluent soluble BOD_5, however, remained within acceptable limits, indicating that efficient capture of suspended and colloidal solids would be the primary method of meeting NPDES effluent quality requirements, after longer sludge ages were made possible.

e) Due to the gross overloading, temperature did not appear to have an identifiable affect on treatment or sludge settling. The limited data seemed to indicate, however, a much larger biological temperature coefficient than reported by other authorities (12).

f) The oil and grease appeared to be readily biodegradable but an excessive quantity was applied to the aerator. With short sludge ages, degradation was not possible, and an excessive amount entered the clarifier and was in the effluent.

g) The high wasting volume required in order to maintain control over effluent solids resulted in excessive depletion of bacteria. This in turn required larger MLVSS in the aerator, but this overloaded the clarifier. Thus the two requirements resulted in opposing operating requirements. The lack of facility capability thus prevented the operation from being optimized beyond the limit of the least capable operating unit, in this case the clarifier.

h) The analysis of the 7 Day monitoring data indicated that the number of occurrences of samples were insufficient to provide a valid basis for predicting effluent quality or designing units based on operating data secured.

i) Overloading any unit of the total system affects data generation and analysis. This is why empirical formulae are suspect, especially if derived from plants operating with one or more units out of balance. For instance, if a final clarifier is too small, providing excessive amount of equilization at the head end of a plant will not result in improved effluent quality. On the other hand, providing adequate clarification for maximum solids loading will eliminate the need for additional equalization.

A preliminary design was prepared based on conventional aerator loading data, F/M ratios, and conservative evaluation of kinetics as derived from the 7 Day data.

Since the kinetic data was suspect, it is not presented in this paper. The valid data is derived from the 34 Day Test is discussed in the next section, together with the appropriate changes in operation and control. However, the same kinetic evaluation procedure was used to derive operational charts for the operators to use for the 34 day test period.

The most important limitation in applying sludge age control is that the kinetics cannot be estimated prior to development of the actual kinetics of a given waste. Once the kinetics are determined, the application to operation is easily accomplished and results are predictable and accurate, once all parts of the process are in balance for the applied loading variations.

The 7 Day test included sampling for heavy metals, Cr, Zn, Fe and Cn. The permit final effluent limitations for Cr was 0.2 #/D daily average, 0.4 #/D maximum day, and for Zn 0.4 #/D maximum day. Based on future design flows, this results in 0.4 mg/l Cr daily average, and maximum day of 0.6 mg/l Cr and Zn.

The September '74 data is of interest in that there was a significant luxury uptake of all heavy metals as well as phosphorus and nitrogen. Considerable amounts were removed in the sludge wastes.

The following tabulation on a concentration basis illustrates this quite well. Although not statistically valid, the results for effluent were well below the required limits and therefore no further sampling or testing was performed during the 34 Day test and due to the high cost for analyses.

Parameters	Average Daily Concentration in mg/1 Influent	Aeration Tank	Effluent
MLSS	--	10,000	--
Org N	10.4	28.3	2.1
$P_{(T)}$	30.4	61.9	4.6
$Cr_{(T)}$	0.07	0.13	0.09
$Zn_{(T)}$	1.2	2.6	0.3
$Fe_{(T)}$	1.3	12.9	N.M.*
$Cu_{(T)}$	0.1	0.4	N.M.*

*N.M. - Not measureable

SECOND TEST PERIOD - 1975

The company officials reviewed the preliminary design and estimated construction costs of over $600,000 submitted in January 1975, based on conservative design criteria.

On about April 1, 1975 the NYSDEC technical review staff informally indicated to Food Company X officials that the design concept was approveable, but in their opinion provided more than adequate modifications to meet final effluent limitations.

The company therefore authorized our firm on April 4, 1975 to proceed with our previously recommended minimum 30 Day test utilizing sludge age control to optimize operation and secure kinetic data for determining design criteria.

The testing began on April 14, 1975.

Initial attempts to control the operation were still made very difficult due to several factors.

a) In order to secure the kinetics, gross overloading of the plant had to be reduced for the test period of managable levels. Operators lacked the means to determine incoming loadings and flow variations frequently enough to decide how much raw waste to remove by scavenger in order to limit overloading of aeration unit. At times Saturday processing was found to be necessary.

b) Air flotation unit could not be operated at optimum pressure, and trash pumps clogged up constantly. Flow rate was erratic, as recycle line valve was manually adjusted after estimates were made of throttling required.

c) The existing B.I.F. float measuring unit had been taken out of service, and a Honeywell measuring unit with a water level sensor was installed late in 1974. This sensor when coated with grease gave high readings and required constant calibration. Weir heads had to be read hourly.

d) Initial attempts to maintain 10-15 days sludge age were only partially effective. Complete control was not maintained, primarily because the sampling and analysis for operation was made every three hours, and wasting once per eight hour shift. This proved to be inadequate since the flow and load changed drastically during a shift and during each hour. This was evidenced by rapid rise and fall of aeration MLSS concentrations.

e) Proper Monday startup equalization fully was difficult since weekend composite data was not available.

f) With added manpower, the hourly sampling, operational sampling and analysis and routine down-time problems, left insufficient time for calculations and review prior to making adjustments. The charts, gages, and controls, were scattered throughout the plant and adjustments to all equipment were manually made. Samples and special measurements were manually secured, and water use meters were read at some distance away from the plant control locations.

g) The need to have better control, more frequent data collection and operation changes, was most evident as when the aerator was turned off. Dissolved oxygen levels dropped from 5-6 mg/l to 0 mg/l in less than 15 minutes.

h) The initial lack of control resulted in several severe overloads on the clarifier, and solids carryover to the effluent for up to several days.

i) Operators reverted to conventional practices whenever problems arose and the engineer was not present.

After three weeks of these problems the testing was suspended on May 2, 1975. Our firm then prepared two operating charts, based on the 7 Day data, with the aim of securing an average sludge age of 8-10 days. Those are Figures 6 and 7. Operators were trained in the use of these two charts, and wasting and flow changes was scheduled every three hours as a maximum. More frequent analysis and changes were made if the plant appeared to be nearing overload conditions, or a rapid change in aeration MLSS was noted, or the sludge blanket in the clarifier began to rise.

The sludge control charts No. 1 and No. 2 were developed from kinetics derived from the 7 Day test in September 1974. Every three hours, or

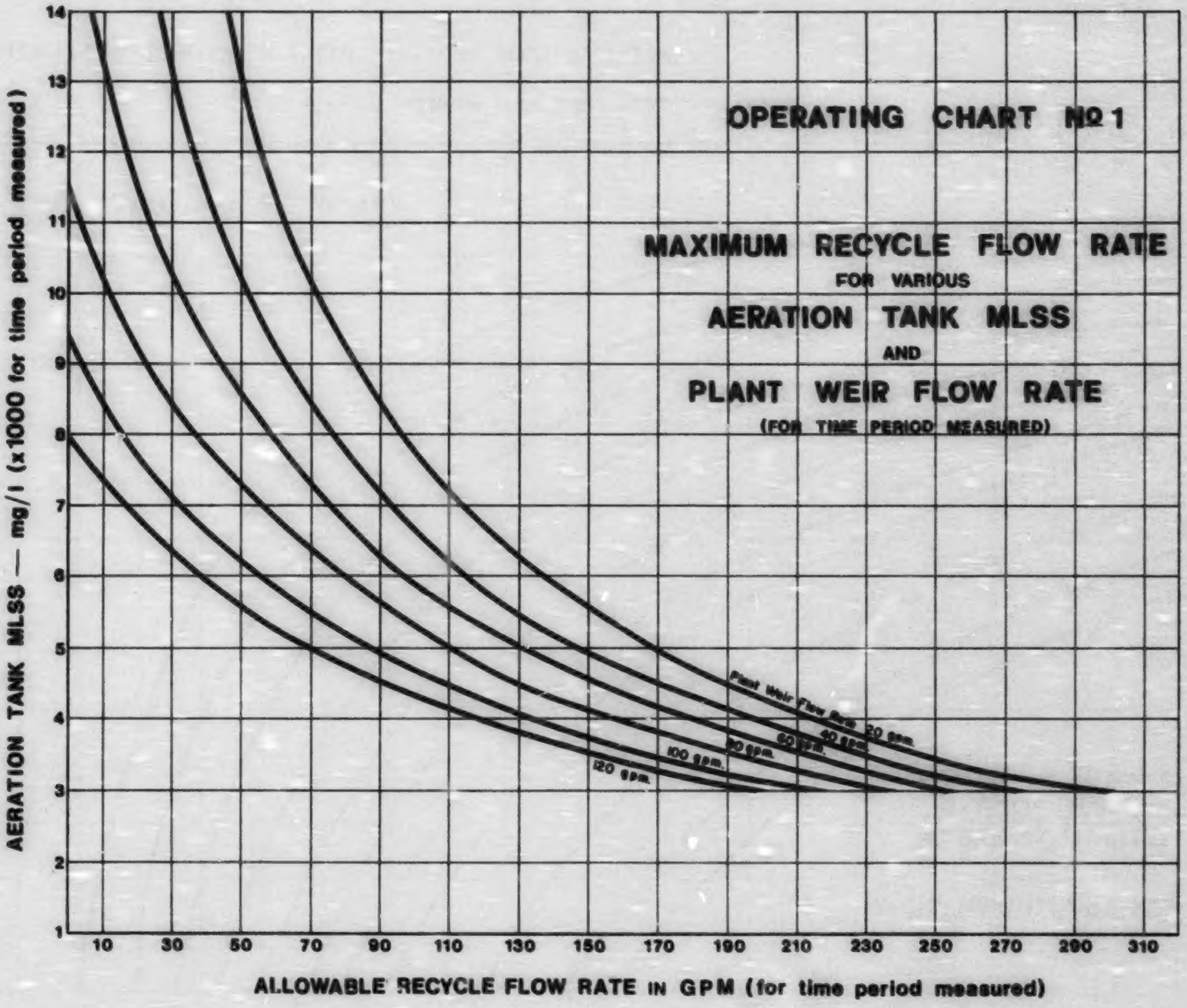


Figure 6. OPERATOR'S CHART No. 1: RAS RECYCLE RATE

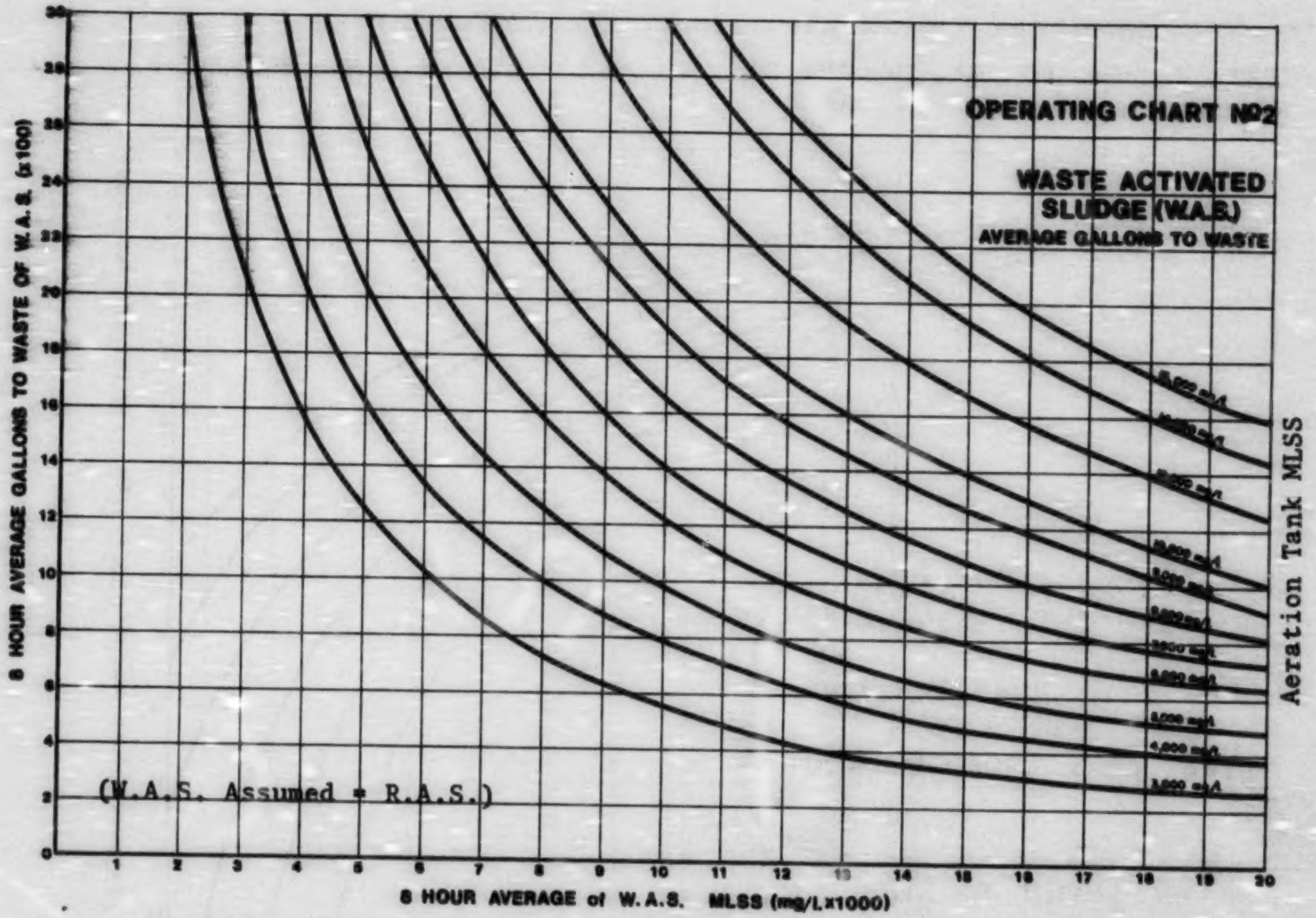


Figure 7. OPERATOR'S CHART NO. 2: WAS WASTING

more often, the operator measured the aeration tank MLSS, the RAS concentration, the weir flow rate and recycle rate. With these measurements, he entered the chart No. 1 and determined the correct recycle rate and adjusted the pump recycle rate accordingly by manually adjusting the valve setting. He entered chart No. 2 and determined the 8 hour wasting volume of TAS to waste and proportioned this amount for the actual hours involved. All other data was taken for our use in developing kinetics and waste characterization.

Testing was resumed on June 9, 1975 and completed on July 3, 1975, with very satisfactory results and a noticeable reduction in operating troubles and downtime.

During this June testing, the D.C.G. unit broke down after two weeks, so that data was secured without D.C.G. filtrate returning to the aerator influent. The effluent BOD_5 levels did not change noticeably from operation with the D.C.G. in operation.

The Honeywell sensor was removed during June; therefore, a drum float recorder was installed for weir flow measurement.

Again, because the raw waste load was not able to be accurately determined, there were several clarifier overloads. For our purposes this was not serious, for we were able to thus determine the maximum capability of the clarifier and other units.

Special data secured during the 34 Day Test were: and B values, zone settling data, oxygen uptake rates, dissolved oxygen levels, extended BOD value, hourly BOD_5 vs flow for a typical day, and temperature and pH at all stations.

Table 3 lists the aerator influent waste characteristics, and Table 4 lists the aerator clarifier operational data. Figures 4 and 5 show the raw waste characterization and overall flow variations data for the complete test periods.

The regular operator's daily report is typified by the June 9, 1975 report reproduced as Figure 8. The additional report sheet showing sludge concentrations and volumes of WAS are reproduced as Figure 9.

The weir flow chart is reproduced as Figure 10 for July 2, 1975. This was a typical flow pattern for the June test period.

FINDINGS

The most noticeable results of applying sludge age control are as follows. Biological unit efficiencies and overall plant efficiencies are given in Table 5. Table 6 lists the official operator's monthly report based on Wednesday's tests for March through September 1975.

SEWAGE TREATMENT PLANT
DAILY LOG

TUES.

DATE: June 10, 1975

VISUAL OBSERVATION: ______________________

TEST	Raw Industrial	Sanitary	Aeration	Clarifier	Final Effluent
Total Solids	9184	2548	6006		1306
Total Solids Fixed					
Total Solids Volatile					
Suspended Solids	5788	1337	5050	–	350
Suspended Solids Volatile	5060	1175	4300	–	300
Suspended Solids Fixed	728	162	750	–	50
Dissolved Solids					
Settleable Solids ½ hour	20	10	990	–	0
Settleable Solids 1 hour(IMHOFF)	20	10	980	–	0
Sludge Vol. Index					
Dissolved Oxygen					
B.O.D. - 5 Day					
Putrescibility or Methylene Blue					
Alkalinity					
Acidity					
Hydrogen Ion Concentration pH	9.8	7.1	7.0	–	7.0
Nitrate - (N)					
Nitrite - (N)					
Ammonia - (N)					
Phosphate					
Color - Turbidity					
Oil/Grease					
Residual Chlorine					
Chemical Oxygen Demand					
Bacteria of the Coliform Group					
Zinc					
Chromium					
Temperature					

Daily Flow

Outfall Gallons per Day: ________________

Usage Gallons per Day: ________________

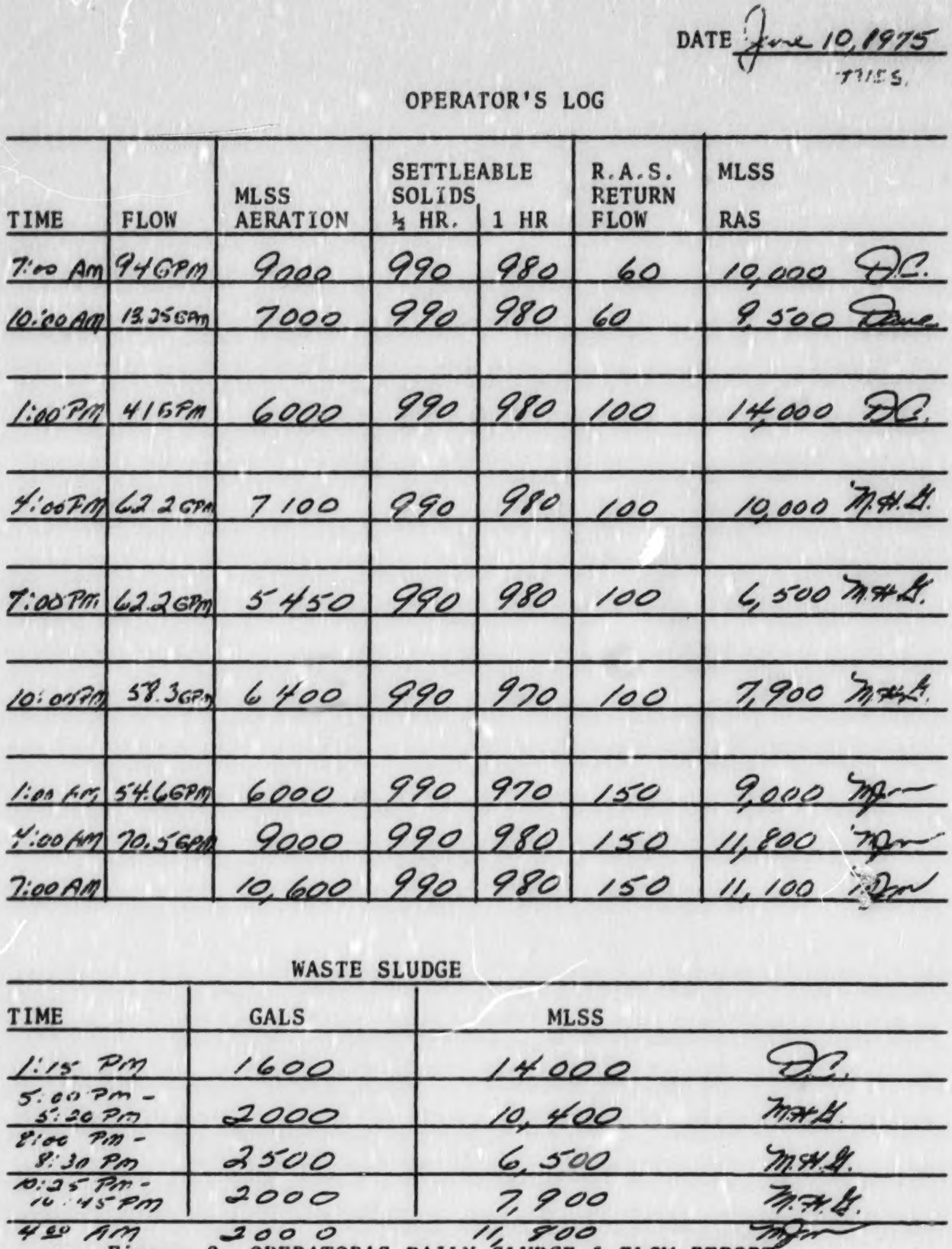
Raw Waste Characteristics

Color: ________________________

Odor: ________________________

Ø=5 days

Figure 8. OPERATOR'S TYPICAL DAILY REPORT



DATE June 10, 1975
TUES.

OPERATOR'S LOG

TIME	FLOW	MLSS AERATION	SETTLEABLE SOLIDS ½ HR.	1 HR	R.A.S. RETURN FLOW	MLSS RAS	
7:00 AM	94GPM	9000	990	980	60	10,000	D.C.
10:00AM	13.25GPM	7000	990	980	60	9,500	Dave
1:00PM	41GPM	6000	990	980	100	14,000	D.C.
4:00PM	62.2GPM	7100	990	980	100	10,000	M.H.G.
7:00PM	62.2GPM	5450	990	980	100	6,500	M.H.G.
10:00PM	58.3GPM	6400	990	970	100	7,900	M.H.G.
1:00 AM	54.6GPM	6000	990	970	150	9,000	
4:00AM	70.5GPM	9000	990	980	150	11,800	
7:00AM		10,600	990	980	150	11,100	

WASTE SLUDGE

TIME	GALS	MLSS	
1:15 PM	1600	14000	D.C.
5:00 PM - 5:20 PM	2000	10,400	M.H.G.
8:00 PM - 8:30 PM	2500	6,500	M.H.G.
10:25 PM - 10:45 PM	2000	7,900	M.H.G.
4:00 AM	2000	11,900	

Figure 9. OPERATOR'S DAILY SLUDGE & FLOW REPORT

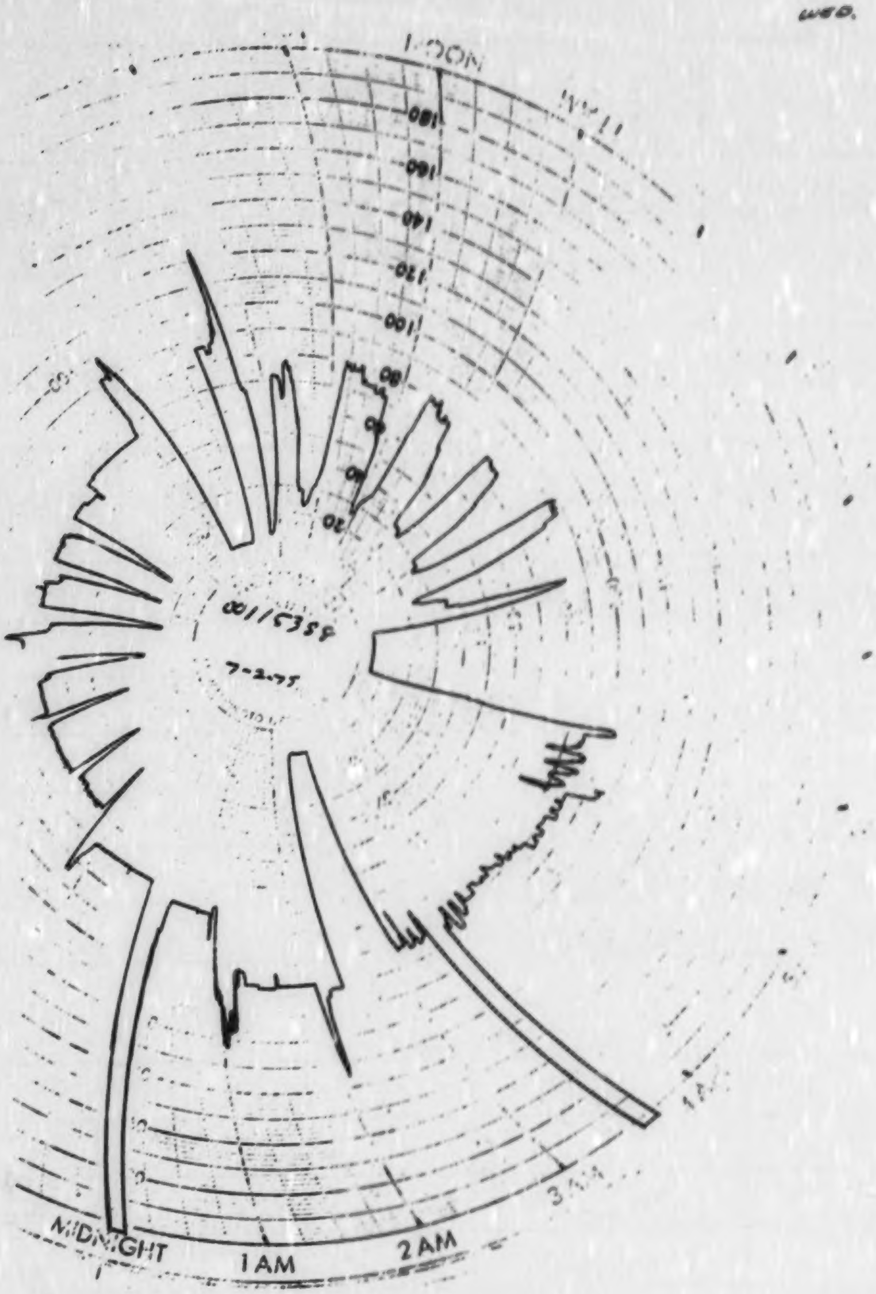


Figure 10. FLOW RECORDER CHART

Table 5. Plant Effluent Characteristics and Removal Efficiencies

Parameter		1968 Design		7 Day Test (1974)		34 Day Test (1975)	
		#/D	% R	#/D	% R	#/D	% R
				Biological System			
$BOD_{5(T)}$	Ave	82.5	90	140	91.3 (87.7 min-97.1 max)	55	90.7
(F)	Ave	-	--	27	98.2	27	95.8
TSS	Ave	24.5	90	85 (110) (max)	91.9 (87.9 min-95.2 max) (5 Day Data)	120	81.9
O&G	Ave	0	--	60	84.0	20 (50 max)	87.0
				Overall Plant Systems Removals			
				5 Days Data			
$BOD_{5(T)}$	Ave	--		140	90.0	--	93.0
(F)	Ave	--		--	--	--	95.8
TSS	Ave	--		85	94.1	--	90.0
O&G	Ave	--		--	--	--	96.5

Table 6. Operator's Monthly Monitoring Report Results

1975 Summer Months - Wednesdays

Parameter	BOD_5 (#/Day)		T.S.S. (#/Day)	
	Ave	Max	Ave	Max
Permit Limit*	23.0	64.0	32.0	72.0
1975				
March	38.7	65.3	25.8	29.7
April	50.4	55.6	67.4	100.4
May	49.6	74.9	90.1	152.9
June	41.4	56.9	17.2	29.4
July	37.4	48.4	243.4	599.7
August	31.9	42.0	56.9	134.3
Sept.	13.6	25.6	23.1	39.6

* Effective until 1/31/76

See text for ultimate limits.

(1) The dissolved oxygen in the aeration tank rose to 5-6 mg/l minimum to nearly saturation values. Under comparable loadings prior to September 1974 no D.O. residual was observed.

Pure oxygen systems, it is noted, generally operate in this range of D.O., which heretofore has been regarded as a major advantage of these systems over air systems.

(2) The clarifier sludge blanket was nearly always controllable even when clarifier neared maximum load. The quick adjustment of recycled RAS from 50% to 40% of forward flow made this possible.

(3) The aeration tank pH was nearly neutral (6.7 to 7.7) at all times due to the excess D.O. available, even though the raw waste pH varied from 4.7 to 8.7.

(4) The plant had fewer downtimes and equipment malfunctions.

(5) The aerator-clarifier BOD$_5$ loading was from 50% to 150% of 1968 design criteria loading. The solids loadings varied from three to seven times 1968 design criteria loading.

In spite of this, the system worked well until the clarifier load exceeded its capability. This occurred about five times. the overloading effect lasted for several days before stable operation resulted (i.e. normal solids in effluent).

(6) Oil and grease were well degraded and effluent contained satisfactory minimal quantities.

(7) Although the range of flow rate was still from 0 to 120,000 g.p.d. during a 24 hour period, the larger flow rates had no affect on clarifier performance, until the maximum permissible loading for a given recycle rate was reached. Only then did the clarifier fail.

(8) The temperature ranged from 5°C to 28°C for the aeration tank influent. There did not seem to be a noticeable effect on overall operation. This appears to be because of tradeoffs between lower sludge yield at lower temperatures, lower settling rates at low temperatures, and higher level of mixed liquor concentration corresponding to lower F/M ratios.

The biological reaction temperature coefficient derived from the 34 Day test data agrees well with referenced authorities (10). The 7 day value however, did not.

(9) The oxygen uptake rate of the MLVSS was found to be comparable to domestic sewage MLVSS at the longer sludge ages. The aerator thus has nearly twice the Horse Power required for oxygen transfer as needed, utilizing sludge age control.

(10) The aeration tank MLSS concentrations ranged up to over 16,000 mg/l during a 3 hour period, and up to about 12,000 gm/l for a 24 hour period, or about 9,500 #/D, considerably in excess of system capacity as determined later.

(11) The effluent BOD_5 substrate was very consistently related to sludge age. See Figure 12. Thus, appropriate capture of clarifier solids (suspended and colloidal) would have resulted in 94± to 96±% removals of BOD_5 over the 34 Day test period.

(12) The sludge age varied between 3 days and 10 days, a very satisfactory range for our purposes. This was achieved utilizing only the two operator charts prepared by our firm.

(13) The sludge settleability has historically been checked by calculating the SVI. Recently it has been noted that industrial process sludges have SVI's which do not correlate with settleability as does sewage sludge.

The SVI of this process waste MLSS during the test period was of limited value to use for control purposes. Most of the time the applied solids concentrations to the clarifier was so high (> 6000 mg/l) that settling was hindered. The standard zone settling test for sewage resulted in very low settling velocities in undiluted settlings tests. Even so, the clarifier solids did not overflow the clarifier weir until the limiting solids flux was reached (as determined later from the test data).

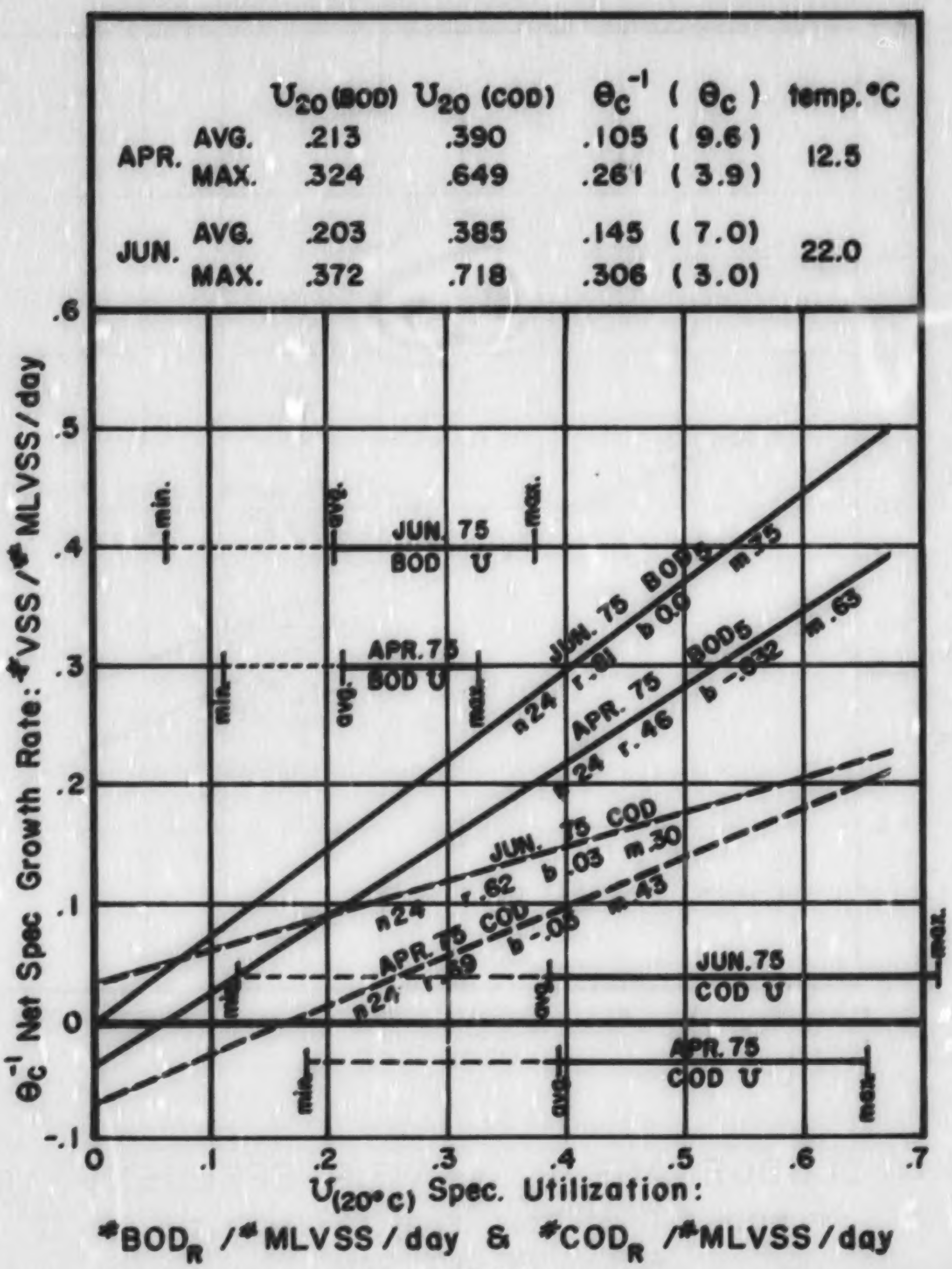
Additional tests demonstrated that the sludge which appeared to be non-settling in a standard SVI liter cylinder, when diluted, settled rapidly and formed a good sludge blanket.

Thus the standard SVI one liter test for sewage MLSS settleability is not a valid or reliable test for settleability of a high concentration process waste MLSS.

CONCLUSIONS

The 34 Day Test Data was analyzed and evaluated. Figures 11, 12 & 13 illustrate the critical parameters needed to establish sludge age control. These are, sludge yield θ_c-1, (the reciprocal of sludge age θ_c), specific utilization U (the true F/M ratio), sludge age θ_c, effluent substrate BOD_5 and zone settling velocity of the clarifier influent solids.

Since this paper is concerned primarily with application to operation, a second paper is under preparation which will present the development of the kinetics from the operating data at non-steady state conditions. Literature research indicates that this can not be successfully done for conventionally designed and operated plants. The application of sludge



		U_{20} (BOD)	U_{20} (COD)	θ_c^{-1}	(θ_c)	temp. °C
APR.	AVG.	.213	.390	.105	(9.6)	12.5
	MAX.	.324	.649	.261	(3.9)	
JUN.	AVG.	.203	.385	.145	(7.0)	22.0
	MAX.	.372	.718	.306	(3.0)	

Figure 11. SLUDGE YIELD (θ_c^{-1}) vs SPECIFIC UTILIZATION (U) CHART

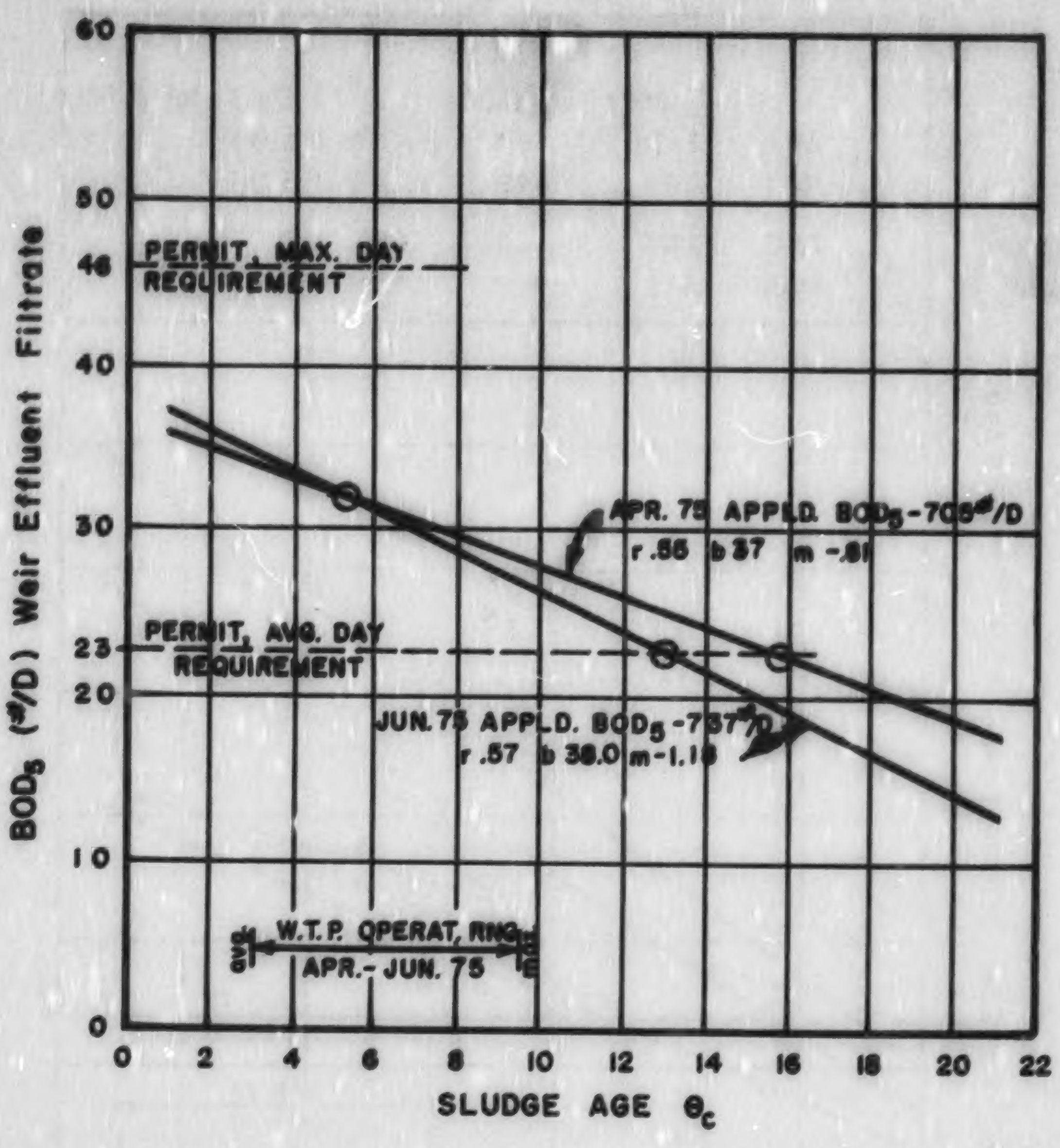


Figure 12. SLUDGE AGE θ_C vs WEIR EFFLUENT BOD$_5$ (Filtrate) for Fully Loaded W.T.P. APR. - JUN., 1975 Data

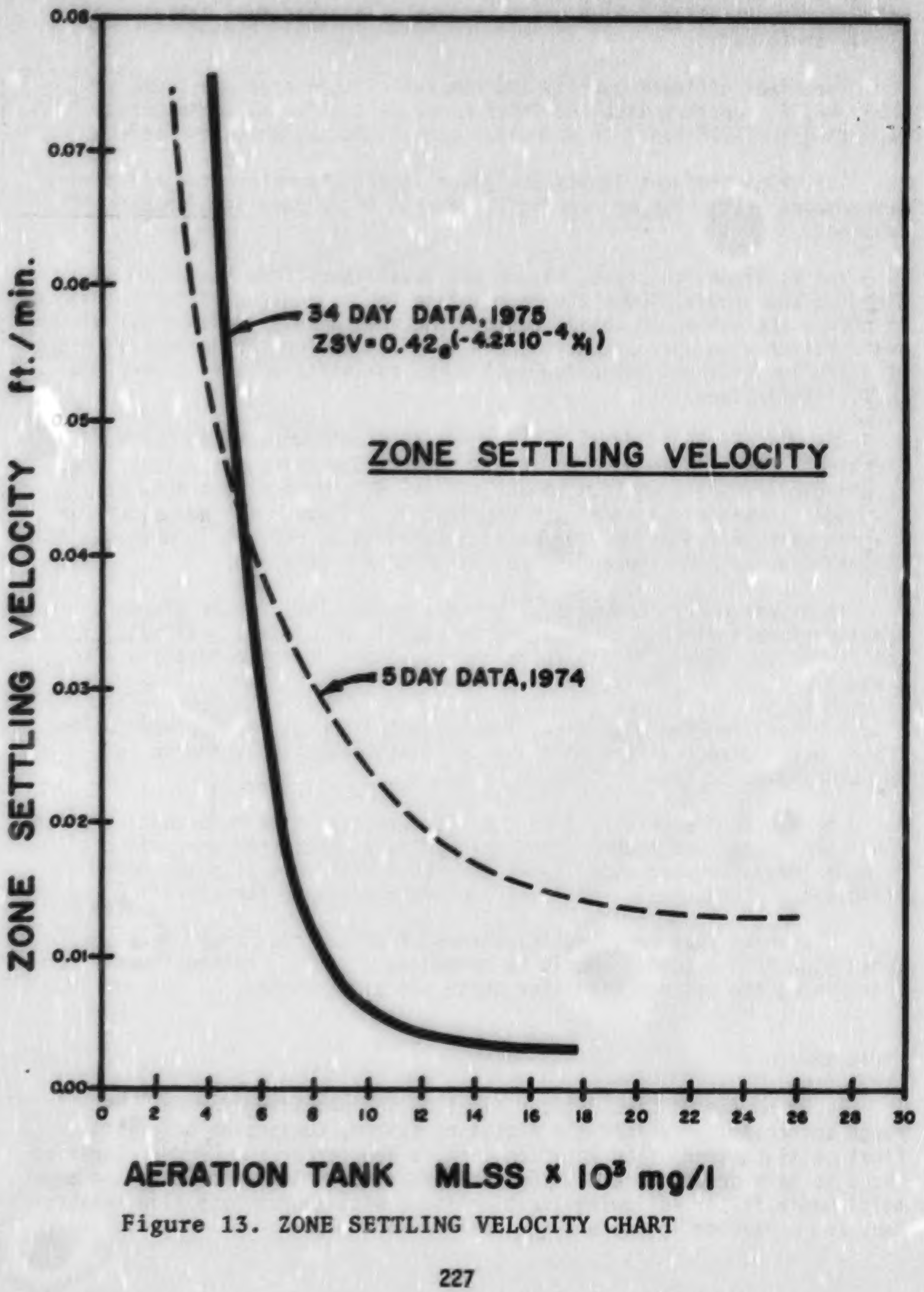


Figure 13. ZONE SETTLING VELOCITY CHART

age control to an existing plant has made it possible to develop the non-steady state kinetics, which are of course more valid than laboratory steady state data.

The final effluent quality and removal efficiencies are found in Table No. 5, together with the Chief Operator's official summer month reporting for 1975 based on Wednesday operations, as shown in Table 6.

The NPDES effluent limits are given in #/D; therefore the efficiency percentages are no longer meaningful, except to compare with comparable loadings.

The final design chart, Figure 12, establishes from the waste's kinetics the proper sludge age to maintain for a required effluent quality of BOD_5. The suspended solids capture requires a multi media or single media filter with appropriate capability of capturing the necessary amount of clarifier effluent suspended solids and colloidal solids to meet the permit limitations.

The clarifier design is based on R. I. Dick's work (11), our modifications, and data secured on the waste settling characteristics. The existing clarifier's maximum capability was at aeration tank MLSS of 7800 mg/l. Even a slight excess resulted in failure. The new clarifier was designed to be optimal for an aeration MLSS of 9400 mg/l, when utilizing the existing aerator and converted clarifier for aeration.

It is extremely important that the aerator-clarifier be sized to complement each other. If not, one unit will immediately restrict the ability of the other unit to function at maximum design conditions and prevent optimum treatment.

In designing the clarifier, the concentration of the applied solids T.S.S. has a direct affect on the actual settleability of the solids, or settling velocity.

Therefore, proper sizing of the clarifier for high MLSS concentrations for a particular waste should be based on MLSS concentrations, and not on empirical hydraulic overflow rates. This will result in the most efficient capture of all settleable solids applied to the clarifier.

It appears that more investigations of actual clarifier operation under high MLSS loadings should be conducted so that a rational basis for determining the optimum clarifier depth can be developed.

FINAL DESIGN

Based on the 34 Days data, a final design providing for raw waste rough screening, a revised air flotation system, conversion of existing final settling tank as an aeration tank, a new larger and deeper clarifier sized to balance economically the total aeration volume provided, and a multi media filter following the clarifier, with appropriate flow measurement and parameter indicators for optimum control.

The estimated construction cost of this design is about $425,000, or about 30% less than the more conservative design.

Figure 14 is the schematic of this proposed final design.

In April 1976 the NYSDEC verbally indicated approval of this revised design to Food Processing Co. X officials. Plans and specs have been authorized by the Company for a June 1976 completion date to comply with a new and revised EPA compliance schedule. The modified plant is to be on line by June 1, 1977. The company plans to have the air flotation unit and multi media filter in service later this fall.

GENERAL OBSERVATIONS

a) One of the most important practical advantages of using the sludge age technology is that all existing plant operators can be easily retrained. It is also not necessary for an operator to have college training or to be a licensed engineer in order to achieve and maintain very high quality effluents.

Special sampling and analysis as required by regulatory permits can be contracted to local certified laboratories, when beyond the analytical equipment capability of the plant.

b) The main disadvantage of conventional systems is their lack of reliability of operation due to lack of control to produce consistently a quality effluent under varying loadings, flow fluctuations and seasonal changes.

Because the effluent quality can now be predicted and effectively controlled by utilization of sludge age control, very effective as well as reliable treatment systems are now available.

c) The author believes that the sludge age control technology is not only applicable at any stage of pollution project development, but is has universal application to all biologically treatable wastes to produce the least costly treatment system for a given effluent quality.

d) Based on our observations so far of this technology in its application to date, and years of searching the literature and reviewing the reported interpretations of the cause of upsets, failures, etc., of conventionally designed and operated treatment plants, the following statement is offered for consideration.

It appears that due to inadequate understanding of the true interrelationship of all components of a treatment plant biokinetic and solids process, all attempts to isolate one component, or treatment unit, and determine the factors most affecting treatment have met with little real success. The profession is still today attempting to determine total kinetics piecemeal and by trial and error, and/or by very complicated methodology and formulae.

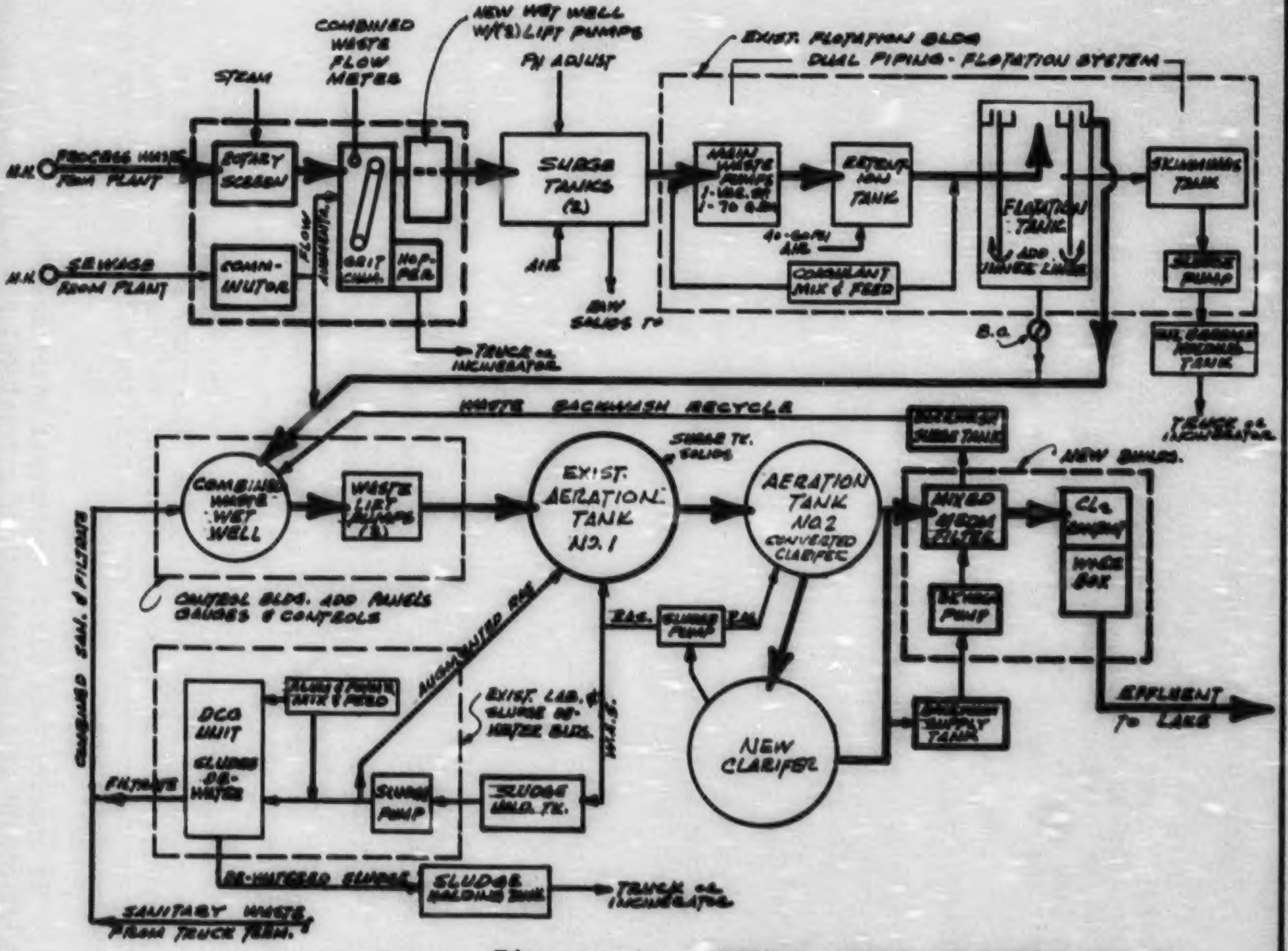

M.H. PROCESS WASTE FROM PLANT
M.H. SEWAGE FROM PLANT
STEAM
ROTARY SCREEN
COMMINUTOR
COMBINED WASTE FLOW METER
FLOW
GRIT CHM.
HOPPER
NEW WET WELL W/(2) LIFT PUMPS
TRUCK OR INCINERATOR
PH ADJUST
SURGE TANKS (2)
AIR
SOLIDS TO
EXIST. FLOTATION BLDG
DUAL PIPING - FLOTATION SYSTEM
MAIN WASTE PUMPS
RETENTION TANK
40-GPM AIR
COAGULANT MIX & FEED
FLOTATION TANK
ADD
B.O.
SKIMMING TANK
SLUDGE PUMP
TANK
TRUCK OR INCINERATOR
WASTE BACKWASH RECYCLE
COMBINED WASTE WET WELL
WASTE LIFT PUMPS (2)
CONTROL BLDG. ADD PANELS GAUGES & CONTROLS
EXIST. AERATION TANK NO. 1
SURGE TK. SOLIDS
AERATION TANK NO. 2 CONVERTED CLARIFER
R.A.S.
SLUDGE PUMP
NEW CLARIFER
SURGE TANK
NEW BLDGS.
MIXED MEDIA FILTER
PUMP
SUPPLY TANK
Cl_2
BOX
EFFLUENT TO LAKE
EXIST. LAB. & SLUDGE DE-WATER BLDG.
W.A.S.
SLUDGE HOLD. TK.
SLUDGE PUMP
MIX & FEED
DCO UNIT SLUDGE DE-WATER
FILTRATE
COMBINED SAN. & FILTRATE
DE-WATERED SLUDGE
SLUDGE HOLDING TANK
TRUCK OR INCINERATOR
SANITARY WASTE FROM TRUCK TERM.

Figure 14. PROPOSED WASTE TREATMENT FACILITY

These are beyond most designers' and operators' ken, and wind up relegated to the bookshelves for ostentatious display of proficiency by association.

The sludge age single control parameter use is practical, is simple to adopt, easy to implement in operation, and to secure the objective within the reliability and accuracy desired. It is less difficult to implement for establishing design criteria as it eliminates considerable guess work where conventional design is concerned.

e) One of the most perplexing problems involved in waste treatment is in regard to those wastes containing so called "toxic" levels of components such as heavy metals, or of intermittent shock loadings of these heavy metals, oil and grease, ammonia, etc.

Based on our findings, there appears to be a luxury uptake of salts and metals in high aerator MLSS in proportion to the concentration and food input. The literature reports that certain concentrations of "toxic" materials are inhibitory to treatment at certain low levels of MLSS concentration. However, the concentration of "toxic" metals may be higher than reported before being considered inhibitory to metabolism of certain stronger wastes or high aerator MLSS.

This may be equally true of nitrogen, phosphorus, etc. Our findings are that the MLSS under aeration will absorb and hold the appropriate amount of trace metals and catalytic material such as phosphorus, needed for optimum metabolism.

Although the total concentrations of metal ions were in excess of recommended levels, no inhibition of treatment was noted.

The high levels of "toxic" metals maintained also provide an acclimated waste and the ability to abort shock loadings.

This therefore can be considered a very important advantage of sludge age control technology and resulting ability of a system to maintain higher MLSS concentrations.

POSTSCRIPT

The Food Processing Company X Chief Operator reports that in April 1976 the Waste Treatment Plant is averaging 98+% removals of BOD_5 with loadings varying from 2000-8000 mg/l per day. S.S. removals are averaging 96% removals. Both effluents are still slightly in contravention of final effluent limitations prescribed by EPA.

Scavenger removal of waste is averaging

8000 gals/wk	surge tank bottom solids
8000 gals/wk	oil & grease float
8000 gals/wk	8%-15% WAS DCG discharge (from 1% WAS)

24,000 gals/wk Total removed

This compares to about 27,000 gals/wk removed during 1975 test periods.

SUMMARY

In conclusion it may be well to look once more at the concept of the single parameter sludge age control. What is it? What can it accomplish? Where can it be used? And what are its limitations?

Sludge age control is the optimization of any biological waste treatment system, where aerated sludge is recycled, by controlling only the active sludge mass age to result in a predictable substrate BOD concentration in the effluent discharge to public waters or a municipal sewer system, resulting in the least costly capital investment and least annual operating costs.

Its application to operation requires no operating tests for BOD, COD, pH, N, P, oil and grease and so forth. It requires sludgge values and flow data only be determined on a frequent basis.

It is applicable at any stage of a pollution abatement project:

a) To existing activated sludge type plant or aerobic digesters

b) During design of a new plant or modifications

c) During construction of a new plant or modifications

d) After completion of a new plant or modifications

e) After a new plant or modified plant is in operation

Modifications are progressively more expensive to implement as the project stage advances from (a) to (e).

No special pilot plant is required for analysis of an existing activated sludge type plant. Once kinetics are determined for an existing waste, it is not necessary to run further pilot studies unless an extreme change in characteristics occurs.

The only apparent limitation to its use is for application to standard trickling filters, oxidation ponds and similar single flow through systems.

It is most effective in cost reduction when applied to sewage waste nutrient removals requirements, in that it permits the use of one stage carbonaceous oxidation nitrification systems and lower chemical requirements for phosphorus removals. This latter is possible because of lowered alkalinity produced by the nitrifiers.

The other most significant technical breakthrough results from applying sludge age control to an existing treatment plant under non-steady state conditions. It is not possible to measure and determine the kinetics of such a biologically treatable waste without the necessity of setting up and operating a pilot plant under laboratory steady state conditions. By properly setting up the testing program and evaluating the data, non-steady state data can be utilized to determine the waste kinetics and be used with confidence for basis of design. The era of empirical basis of design is past - now comes the era of rational basis of design for biologically treatable wastes.

Standard Operation Form

Due to the continuing plant overloading, the company decided to continue intensive sampling and data acquisition for operator use in maintaining optimum control until the plant modifications were built. To facilitate this, Chief Operator Chester prepared a comprehensive operation form which was placed in use in September 1975. See Figure 15-1 and 15-2.

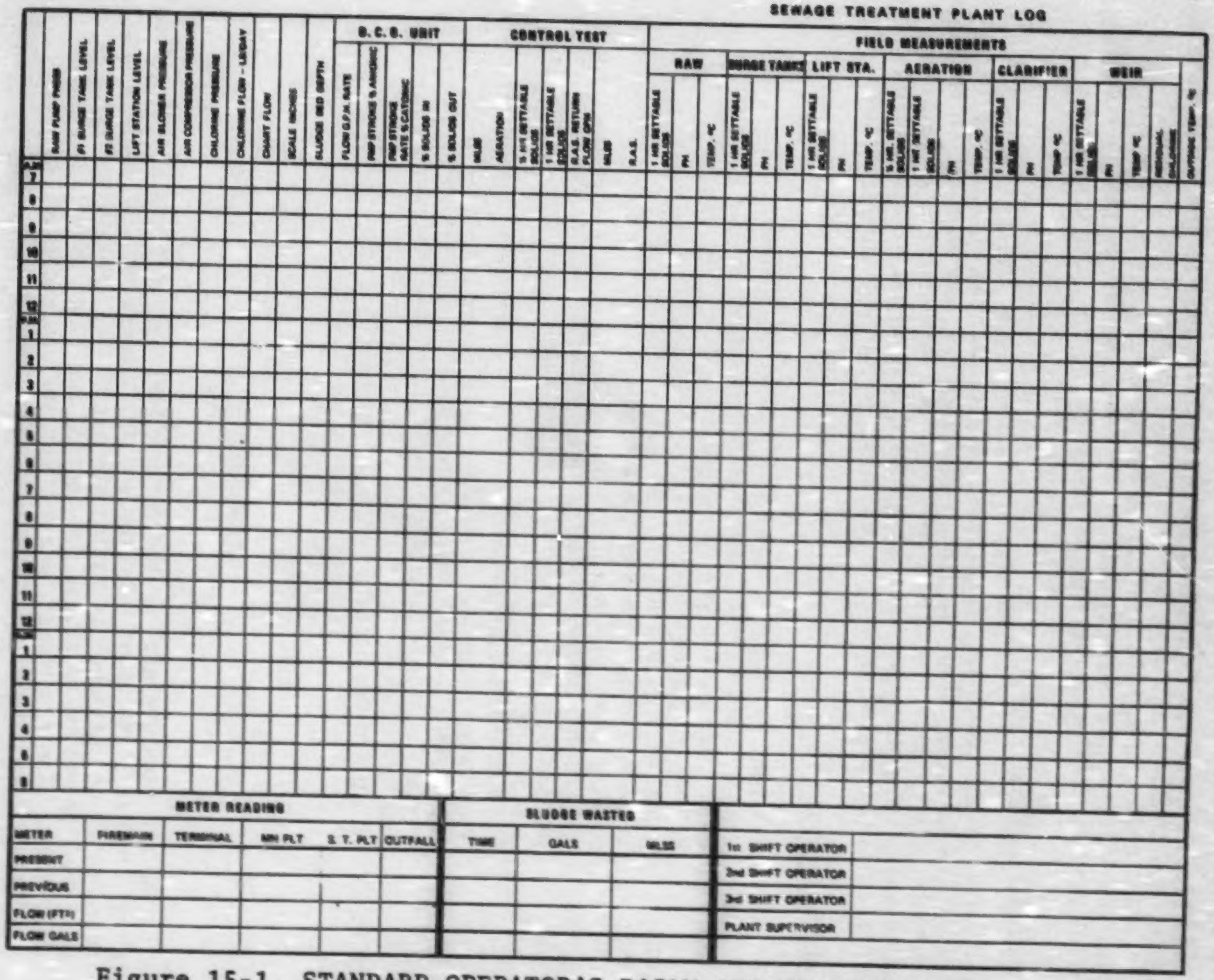
Abbreviations Used

NPDES	National Pollutant Discharge Elimination System
NYSDEC	New York State Department Environmental Conservation
EPA	Environmental Protection Agency
RAS	Return Activated Sludge
WAS	Waste Activated Sludge
DCG	Dual cell gravity sludge thickener unit
SVI	Sludge Volume Index
gpsfd	gallons per square foot per day
gpd	gallons per day
gpwk	gallons per week
gpm	gallons per minute
SWD	side water depth
HP	Horse power
O_2	Oxygen
hr	hour
D.O.	Dissolved Oxygen

ACKNOWLEDGMENTS

We are very grateful to the various Company X officials: Vice President, Chief Engineer, and Chief Operator and shift operators for their support, cooperation and patience in making the successful transition from conventional operation to sludge age control operation under severe operating conditions. Their personal interest was most appreciated.

Mr. Gerald L. Strobel, P.E., Chief Engineer of Ecology & Environment, Inc., Cheektowaga, New York and his Laboratory Chief, Rocco Termini, provided excellent and high quality technical assistance in analyzing and reporting a multitude of data.



SEWAGE TREATMENT PLANT LOG

												D.C.G. UNIT					CONTROL TEST					FIELD MEASUREMENTS																				
																						RAW			SURGE TANKS			LIFT STA.			AERATION				CLARIFIER			WEIR				
	RAW PUMP PRESS	#1 SURGE TANK LEVEL	#2 SURGE TANK LEVEL	LIFT STATION LEVEL	AIR BLOWER PRESSURE	AIR COMPRESSOR PRESSURE	CHLORINE PRESSURE	CHLORINE FLOW - LB/DAY	CHART FLOW	SCALE INCHES	SLUDGE BED DEPTH	FLOW G.P.M. RATE	PMP STROKE % ANIONIC	PMP STROKE RATE % CATIONIC	% SOLIDS IN	% SOLIDS OUT	MLSS AERATION	½ HR SETTABLE SOLIDS	1 HR SETTABLE SOLIDS	R.A.S. RETURN FLOW GPM	MLSS R.A.S.	1 HR SETTABLE SOLIDS	PH	TEMP. °C	1 HR SETTABLE SOLIDS	PH	TEMP. °C	1 HR SETTABLE SOLIDS	PH	TEMP. °C	½ HR. SETTABLE SOLIDS	1 HR SETTABLE SOLIDS	PH	TEMP. °C	1 HR SETTABLE SOLIDS	PH	TEMP °C	1 HR SETTABLE SOLIDS	PH	TEMP °C	RESIDUAL CHLORINE	OUTSIDE TEMP. °C
A.M. 7																																										
8																																										
9																																										
10																																										
11																																										
12																																										
P.M. 1																																										
2																																										
3																																										
4																																										
5																																										
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A.M. 1																																										
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4																																										
5																																										
6																																										

METER READING

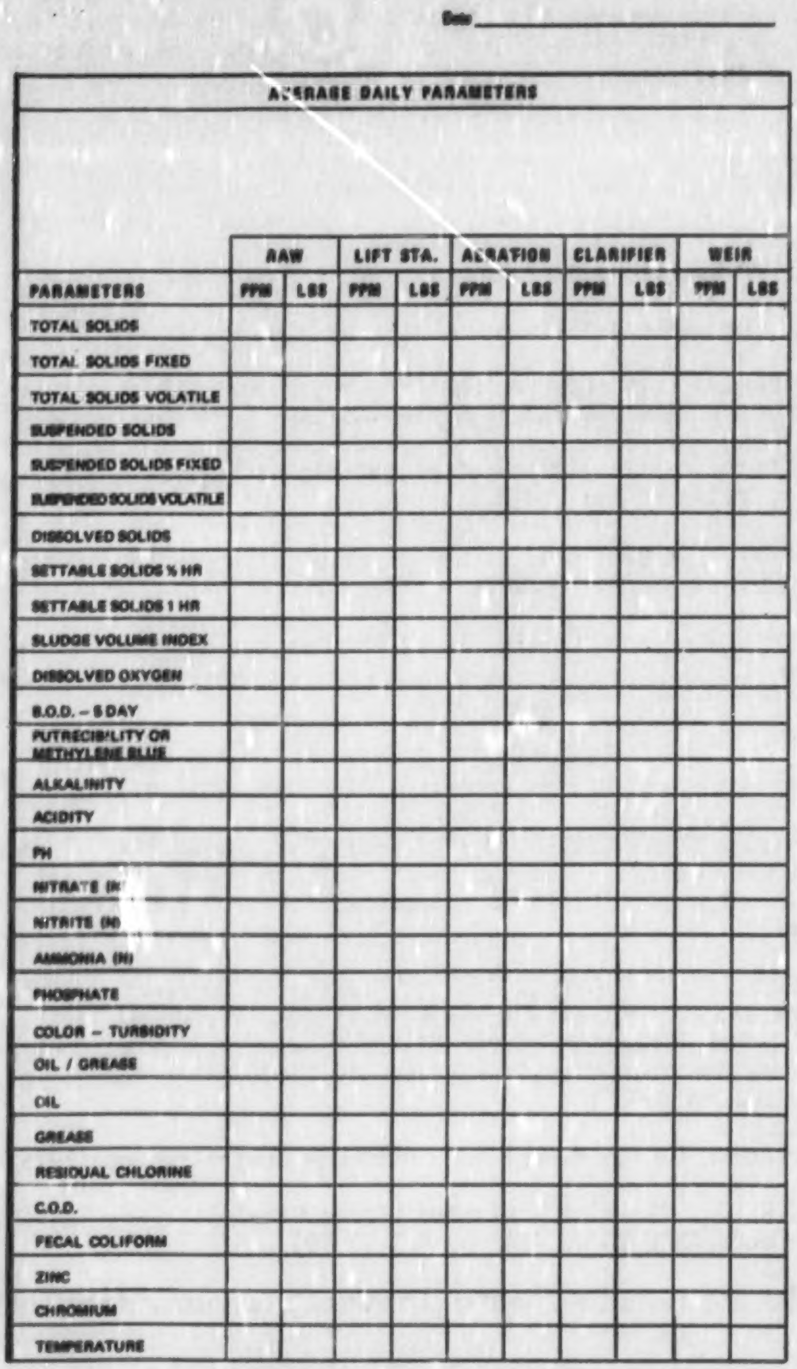
METER	FIREMAIN	TERMINAL	MH PLT	S. T. PLT	OUTFALL
PRESENT					
PREVIOUS					
FLOW (FT³)					
FLOW GALS					

SLUDGE WASTED

TIME	GALS	MLSS

1st SHIFT OPERATOR	
2nd SHIFT OPERATOR	
3rd SHIFT OPERATOR	
PLANT SUPERVISOR	

Figure 15-1. STANDARD OPERATOR'S DAILY REPORT FORM (Adopted 9/75)



Date ______________________

AVERAGE DAILY PARAMETERS

	RAW		LIFT STA.		AERATION		CLARIFIER		WEIR	
PARAMETERS	PPM	LBS	PPM	LBS	PPM	LBS	PPM	LBS	PPM	LBS
TOTAL SOLIDS										
TOTAL SOLIDS FIXED										
TOTAL SOLIDS VOLATILE										
SUSPENDED SOLIDS										
SUSPENDED SOLIDS FIXED										
SUSPENDED SOLIDS VOLATILE										
DISSOLVED SOLIDS										
SETTABLE SOLIDS ½ HR										
SETTABLE SOLIDS 1 HR										
SLUDGE VOLUME INDEX										
DISSOLVED OXYGEN										
B.O.D. – 5 DAY										
PUTRECIBILITY OR METHYLENE BLUE										
ALKALINITY										
ACIDITY										
PH										
NITRATE (N)										
NITRITE (N)										
AMMONIA (N)										
PHOSPHATE										
COLOR – TURBIDITY										
OIL / GREASE										
OIL										
GREASE										
RESIDUAL CHLORINE										
C.O.D.										
FECAL COLIFORM										
ZINC										
CHROMIUM										
TEMPERATURE										

Figure 15-2. STANDARD OPERATOR'S DAILY REPORT FORM
(Adopted 9/75)

A special note of thanks to Gerald L. Devlin, P.E., my partner and Vice President of Brown-Devlin Associates, P.C. who provided invaluable technical expertise, counsel and advice throughout the project and preparation of this paper.

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CONTROL OF COLOR PROBLEMS DURING RECYCLING OF FOOD PROCESS WATERS

A. Hydamaka, P. Stephen, R. A. Gallop and L. Carvalho
Food Science Department, University of Manitoba
Winnipeg, Manitoba R3T 2N2 Canada

INTRODUCTION

Of immediate concern to the food processing industry are the legislative guidelines with deadlines set for 1977 and 1983, for reduction of waste effluents and the use of best available technology, with the aim of zero discharge by 1985.

To deal with the above guidelines, the EPA and the U.S. food processing industry began in 1970, a national program of research, development and demonstration of pollution control methods. The First National Symposium on Food Processing Wastes (1) suggested that goals include the development of processes capable of high degrees of treatment, the design of processing methods to reduce the quantity of water required, the possible recycling of water, the development of profitable by-products from the recovered processing "wastes", and the ultimate disposal of sludges and other residues.

There are only limited reports in the literature, where water recycling in the food industry has become a reality (2, 3, 4, 5, 6, 7). As an example of what can be widely achieved, this paper will discuss the potential of a closed-loop recycle system at the rinse stage of potato processing as part of the "total systems" concept approach to the food industry. Water used at this processing step will leach from the surface of the potato slices color forming compounds such as enzyme substrates and enzymes. The colored process water may be undesirable from an aesthetic viewpoint as it is foamy as well, with appreciable microbial populations, and also may promote further development of browning if recirculated upon freshly exposed food tissue, while also discoloring the latter. Browning reactions are important for quality control in terms of the alteration of appearance, flavor, nutritive value and possible toxicology.

Conventionally, potato processing plants dump their wastes to municipal sewage disposal systems. This practice is no longer usually acceptable as sewage surcharge costs have increased dramatically in recent years. Primary and secondary treatment facilities on-site, only duplicate the municipal waste treatment system. Industry is faced with increased costs to meet the proposed guidelines for 1977 and 1985. For frozen potato products, the maximum daily discharge in lb/ton is set at BOD, 9.5, TSS, 17.5, in 1977, and BOD, 1.6 and TSS, 2.7 in 1983 (8).

Most of the pollution problems faced by the food industry have arisen because for too long the industry has followed the "linear-process" once-use system (Fig. 1) rather than cyclic systems (Fig. 2), with waste treatment thought of as an added investment yielding no return as a result. EPA studies conclude that at least 100 food processing plants will soon go out of business because of pollution controls and at least another 300 may be similarly affected (9).

The potato processing industry has made significant advances in recent years in pollution control at the slice-rinse stage, by recovery of products for commercial sale, and in reduced water use. The C-E Bauer Company (5) reported that by use of the hydrasieve screen and cyclone, a potato processing plant received $439 per day in solid waste products, and also saved $18,000 per year in sewage charges. Net pay-off of the initial investment of $135,000 was about one year's operation. The J. D. Ferry washer system (6) resulted in an annual savings of $11,000 to a potato plant. The Perfect Potato Chip plant in Decatur, Illinois has installed the Sweco recovery system, and expects to earn an annual gross revenue of some $10,000 through starch reclamation (7). The above systems demonstrate to the food processor that in some areas pollution control at the sources can be a profitable venture.

The slice-rinse process proposed by the authors would include the above systems for removal of solids such as starch. However, there would be complete recycling of the starch-free rinse water with only a minimal amount of make-up requirement. For recycling of the rinse water, quality control factors such as physical, physical-chemical, biochemical and biological factors, must be regulated. Included are the factors of "color, odor, foam, and bacterial build-up." The use of activated carbon may be the essential key to controlling all these factors. The present practice of chlorination for bacterial control (now a controversial topic in wastewater management due to potential health problems), the costs, supply problems, and the need for massive dilution, requiring much fresh make-up water, would be eliminated.

The use of activated carbon and water recycling is part of our total systems concept to the food industry. The concluding remarks of the Fourth Symposium (1973) (10) suggested that this approach is the most ideal solution to water and waste management in the food processing industry. Using this approach former elements of waste become as important as the intended commercial products.

The agricultural-food processing industries are largely producers of solid wastes and wastewater. In the case of agronomic solid wastes, the industry is faced with the disposal of massive amounts of wet carbohydrate material, often of low economic value yet presenting a major potential for costly treatment and disposal, so as to avoid causing pollution. Such "wastes" are important on-site, to the total system concept proposed. The authors have found that conversion of such wastes into activated carbons, has produced adsorbents which are equal to or superior to commercially available carbons (11). These carbons are then highly used in cyclic loops, to rapidly reclaim process water, to permit continuous recycling of such "aids" at each step, to a very high degree, without serious problems.

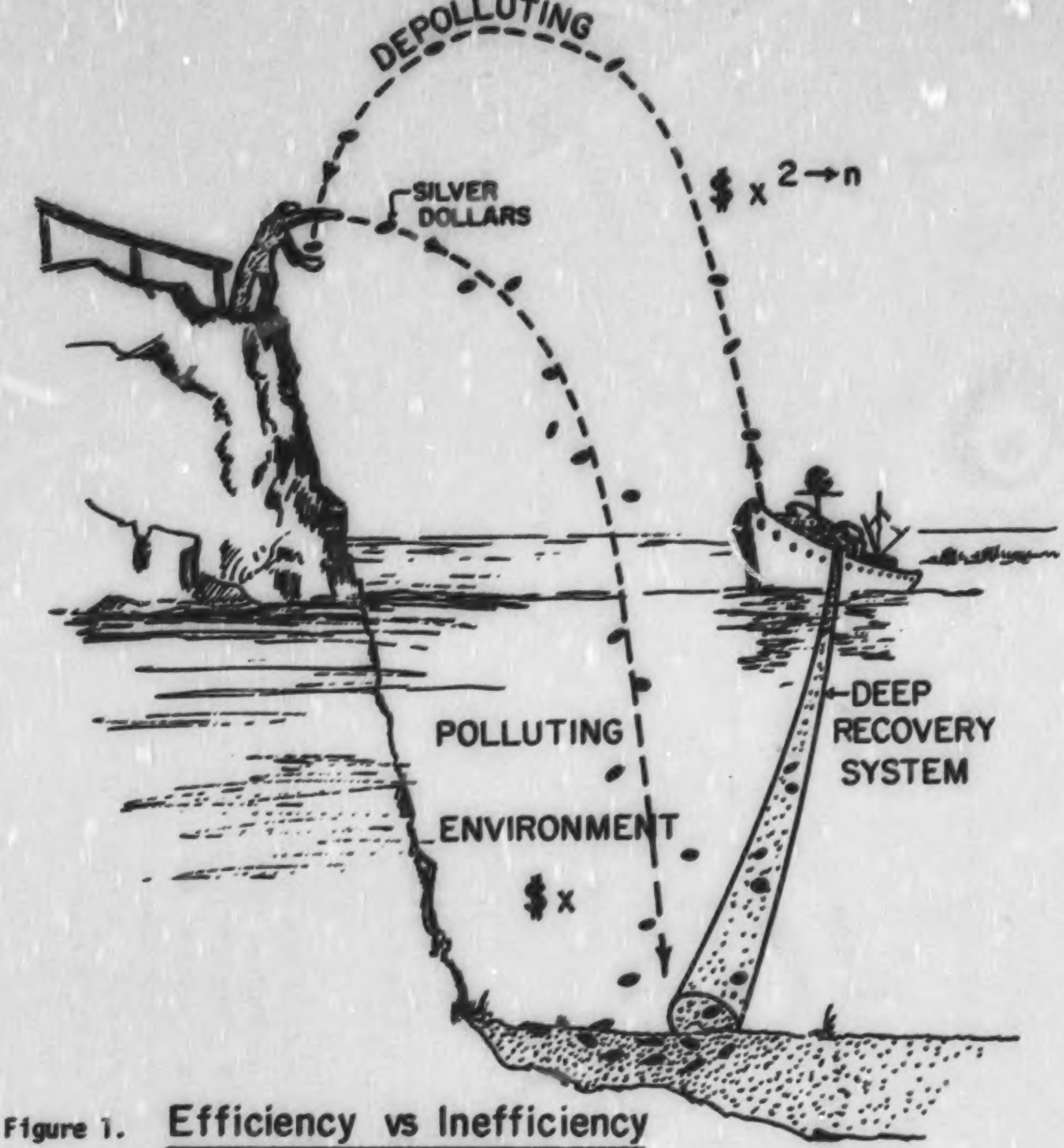
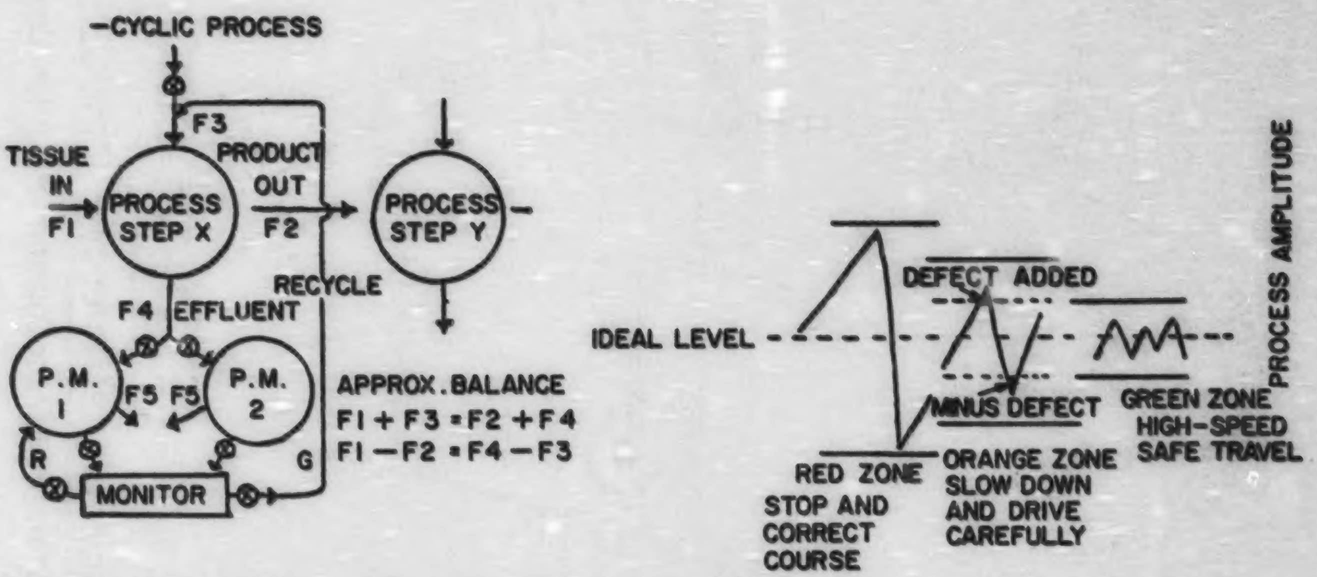

DEPOLLUTING
SILVER DOLLARS
$ x 2→n
POLLUTING
ENVIRONMENT
$x
←DEEP RECOVERY SYSTEM

Figure 1. Efficiency vs Inefficiency

Cyclic System vs Linear System + Pollution Control

$\$\,dx$ vs $\$\,(x + x^{2 \to n})$

Figure 2. AUTOMATIC, HIGH EFFICIENCY QUALITY CONTROL SYSTEMS


-CYCLIC PROCESS
F3
TISSUE
IN
FI
PROCESS
STEP X
PRODUCT
OUT
F2
PROCESS
STEP Y
RECYCLE
F4
EFFLUENT
P.M.
1
F5
F5
P.M.
2
R
G
MONITOR
APPROX. BALANCE
FI + F3 = F2 + F4
FI − F2 = F4 − F3
IDEAL LEVEL
DEFECT ADDED
MINUS DEFECT
RED ZONE
STOP AND
CORRECT
COURSE
ORANGE ZONE
SLOW DOWN
AND DRIVE
CAREFULLY
GREEN ZONE
HIGH-SPEED
SAFE TRAVEL
PROCESS AMPLITUDE

Symbols: P.M. — Purifier modules, one on load, one on standby
W — Waste solids, to use or destruction
R — Reject for re-purification or discharge
G — Accept for re-use
V — Cyclic base volume
dV — Make-up volume/cycle
n — No. of re-use cycles

The potential use for carbon in such systems has been enhanced by a fast process, the "Atomized Suspension Technique", which regenerates and recovers powdered carbon in about 30 seconds (12) at low costs and high yields (90% recovery and 95% of reactivation of adsorbing capacity).

The Proper Sequencing of the Sciences in Engineering Systems

Nature has obviously been created in a hierarchical, rational pattern beyond basic change by man, which we must adequately understand and respect if our practical engineering systems are to succeed, plus be efficient and economical. Figure 3 schematically shows the "power-structure" of the sciences, and of their interdependency in practical situations on each other, and of course, on the great constant, time, to which all of them but mathematics, which preceded, and which rules all of them in quantitative terms, must submit.

All processes, in natural and man-made systems, must follow the sequence of the sciences shown in Figure 3 qualitatively and quantitatively, in time. Thus if we gather such data on a particular process, as we do, step by step in a process line, then we can easily see how to improve the process itself, its control, efficiency, and cost. Then predictive ways to greatly improve processing equipment, product quality control, and its mirror-image, reduced water and waste-management problems, along with smaller, simpler systems for handling them, plus the costs and environmental constraints involved, are all opened up widely to our advantage. In Sweden, only the most efficient processors have survived the environmental constraints, and those who improve their processes as we suggest should do well competitively in every way.

The Q. C. Criteria in Water-Food Relationships

The quality characteristics of each grade of acceptable water must be defined by the intended role/s for it. The human judgements expressed as quality control criteria about the relative significance of the physical, physico-chemical, biochemical and biological factors (see Figure 3) likely to be in the water, or required to be in it, to enable the intended function of it to be achieved efficiently express the maximum limits of undesirables and the minimum limits of desirables (Figure 4), that should be in each grade of water for each function.

The concept of "background levels" is very important in the management of resources, especially water, air, land, and food composition. It is foolish to try to work below natural background levels of exposure in most situations. Over-purification of water before and after use, in huge volumes, is a major cause of inefficiency in water-management. In virtually "closed-loop" cyclic systems, purification needs and volumes/cycle are always minimal. With repetitive use, all factors build up to equilibrium background levels at appropriate rates (see Figure 5). The only purification needed between uses is to keep each factor below a level where they can cause significant defects in the system (e.g., by failing to remove enough residual soil each cycle from foods being washed). The defects (pollutants) added to the water each pass can be determined and adjusted; systems for their automatic water for them can be determined and adjusted; systems for their automatic deduction from such a flow (at appropriate rates equal to or greater than

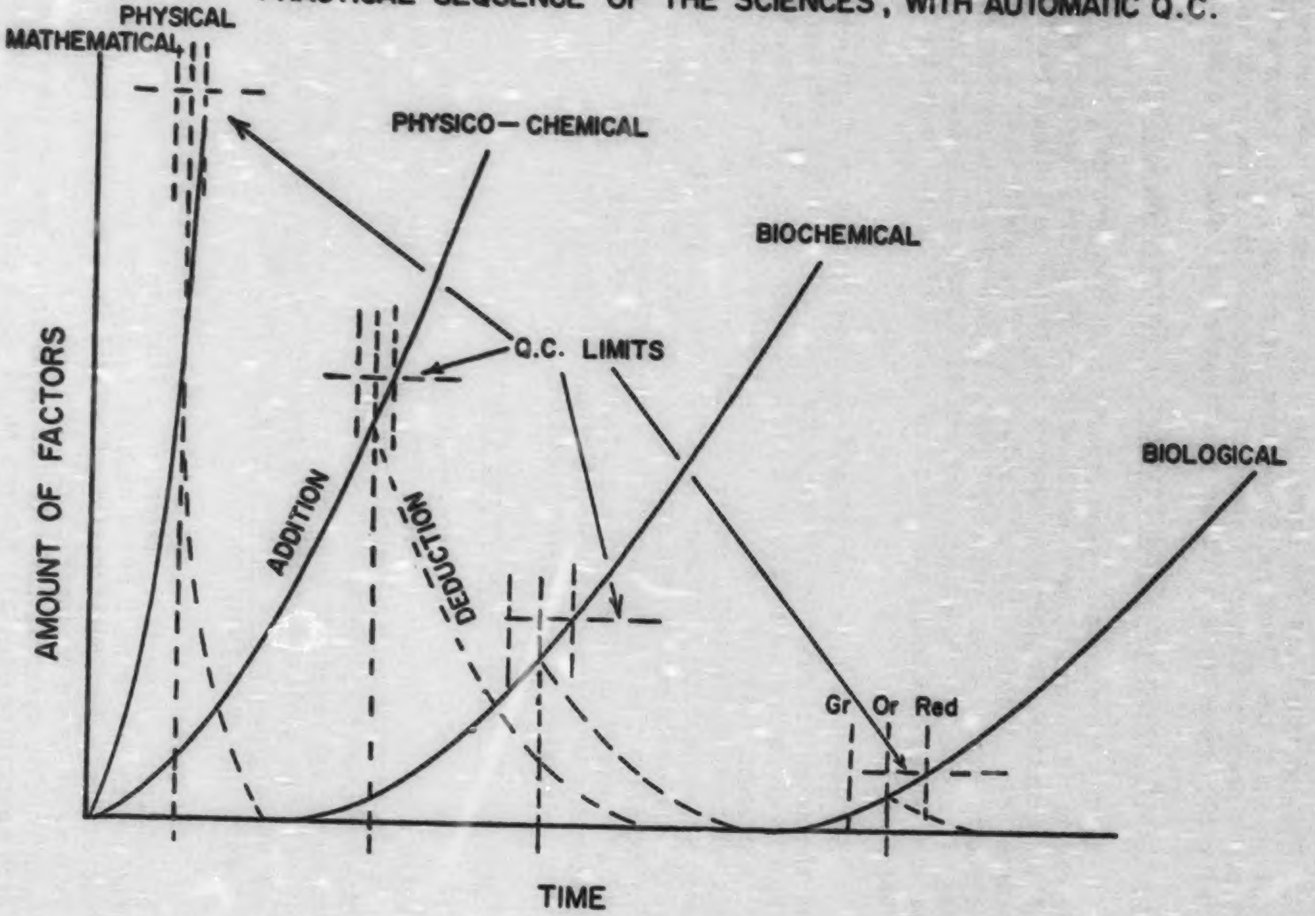
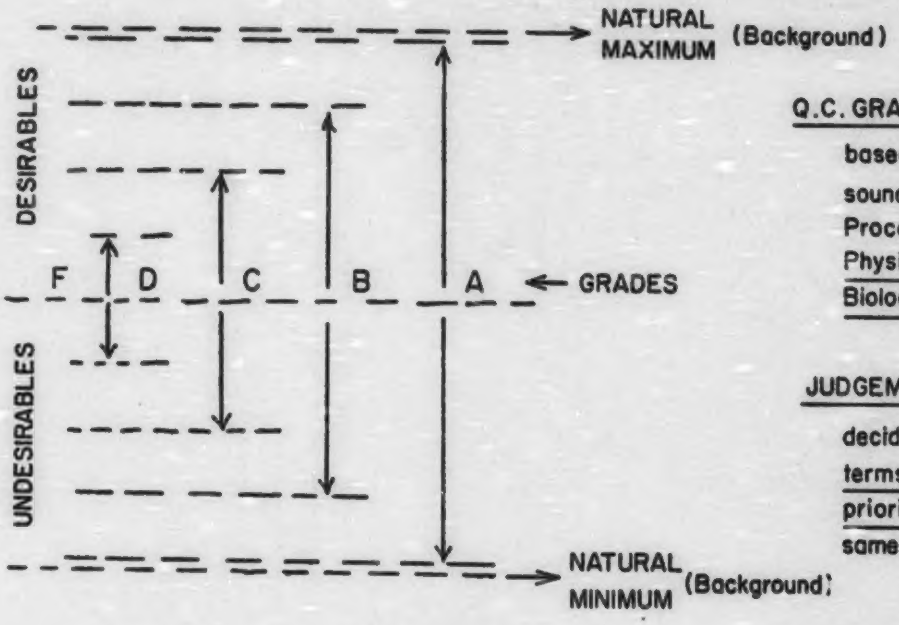


Figure 3. PRACTICAL SEQUENCE OF THE SCIENCES, WITH AUTOMATIC Q.C.

Figure 4. QUALITY CONTROL CRITERIA


NATURAL MAXIMUM (Background)
DESIRABLES
F
D
C
B
A
GRADES
UNDESIRABLES
NATURAL MINIMUM (Background)

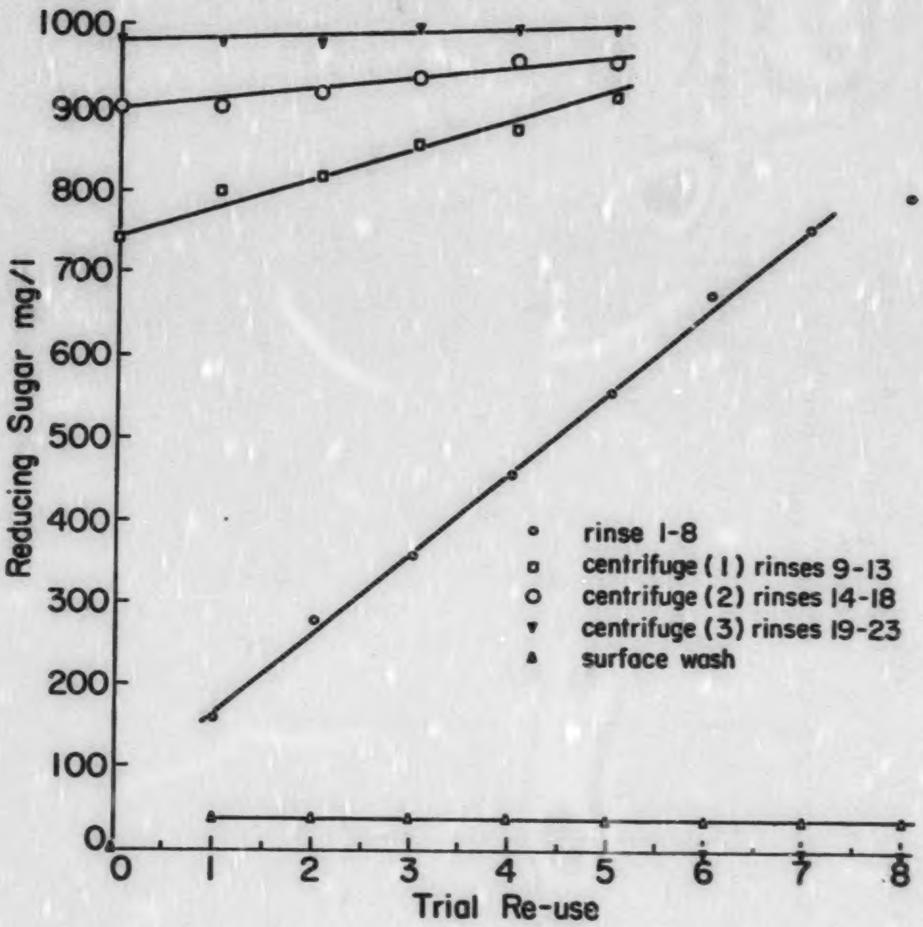
Q.C. GRADES ARE BENEFIT/COST JUDGEMENTS,

based on Numbers, derived from scientifically sound, Sampling, Analytical, and Statistical Procedures, for the determination of Physical, Physico-Chemical, Chemical-Biochemical, Biological, Aesthetic, and Economic Factors.

JUDGEMENTS ABOUT Q.C. GRADES,

decide the relative significance in quantitative terms, of these Factors, in reasonable priorities, in a Process step, or sequence of same, for given functions.

Figure 5. REDUCING SUGAR CONTENT OF RECYCLED FRENCH FRY RINSE WATER



their likely rate of addition with recyclic water use) should then be installed in-line (just like a thermostatic cooler for heating systems, or a cartridge filter on our car crankcase oil cyclic system) to maintain the quality of the water within the green or orange-light zone (see Figures 2 & 3) almost infinitely. If we set-up such systems at each function where water is used to deduct excessive levels of undesirables and make-up deficiencies of desirables (e.g., as is done for condensers and boiler-feed waters), and is readily possible now, by on-line cartridge devices, in most situations, very high degrees of re-cycling on-site become readily possible in a wide range of situations, at slight costs, in every way.

As the recycling number "n" is increased, the input volume V required, and the supply equipment capacity drops from V to $\frac{V}{n}$, the discharge "blowdown" for excess solute removal (as in a boiler) becomes $\frac{V}{n}$, pumping costs will rise somewhat, the collection and treatment system becomes $\frac{V}{n}$ in volume, and very much less than this in operating costs. And finally, significant environmental pollution can be avoided when returning the spent materials to nature.

If our cars were built the way most of our industry, university, governmental and domestic water-using systems are designed (e.g. on the linear flow-sheet) they would be unusuable. We can only use and afford them because their water and oil systems were rationally designed on the cyclic model almost a century ago. A moment's reflection on this paradox gives us an idea of how much productivity and freedom we can readily regain by using sensible engineering systems for water, air, and other processing fluids everywhere at costs very much lower than we are now carrying, with great gains, in many ways, while conserving and protecting our resources and environment.

EXPERIMENTAL SECTION

Enzymic browning in the food processing industry has always posed problems for food processors. Such enzyme systems also must be considered when dealing with a closed loop cyclic system in the rinsing of french fry slices.

Browning of potato tissue on exposure to air (oxygen) is the result of action of the phenolase complex on organic constituents present in the potato. This enzyme or complex can be divided into two types of reaction: the phenol hydroxylase or cresolase activity, and the polyphenol oxidase or catecholase activity. In the potato tuber, Schwimmer and Burr (13) have found that the main substrate for the phenolase enzyme is L-tyrosine. It has been shown that tyrosine is first converted to a diphenol compound by cresolase activity and that this intermediate compound (3, 4-Dihydroxyphenylalanine) is oxidized by catecholase activity into a corresponding quinone (o-quinone phenylalanine). Removal of hydrogen results in the formation of a red compound, dopachrome (5, 6-quinone indole-2-carboxylic acid) which subsequently undergoes polymerization to form brown melanin compounds (14).

It is obvious, therefore, that by removing substrate and/or enzyme from solution, the browning reaction can be controlled. Activated carbon has long been used to remove color and odor from various solutions, and was therefore used in this study, to attempt to control the browning problem found in recycled rinse water.

The role that carbon would play in the reduction of "browning" was observed by measuring the activity of the polyphenol oxidase enzyme and the level of hydroxylated aromatic compounds present in solution, before and after treatment.

Method for Determination of Enzyme Activity

The activity of the polyphenolase enzyme was measured by calculating the initial velocity of the enzyme when a standard volume (0.20 ml) of potato rinse water was combined with a standard volume (3.0 ml) of buffered catechol solution (.01M, pH 6.0).

The equipment used for measurement of the initial velocity of the enzyme included a Coleman UV-111 spectrophotometer, a Unicam SP45 Concentration Readout Unit (used to set the range of the recorder from 0.0-0.20 absorbance) and a Unicam AR25 linear recorder.

PROCEDURE

A 0.01M catechol solution (pH 6.0) was prepared by pipetting a 15 ml aliquot of a 0.2M disodium hydrogen phosphate solution and a 110 ml aliquot of a 0.2M sodium dihydrogen phosphate solution into a 250 ml volumetric flask, adding 0.2753 g of categhol and making the flask up to volume with deionized water. The solution was aerated at room temperature before analysis.

The wavelength used for the analysis was 410 nm. A "control" solution was used to set the absorbancy of the spectrophotometer to 0. Three ml of the buffered catechol solution was placed in a 10 mm cuvette. To this was added 0.20 ml of deionized water. The cell was inverted several times and the instrument adjusted to 0 and the scale expansion unit and recorder set so that full scale deflection would be achieved at an absorbancy of 0.20.

The above procedure was repeated for an actual sample, but on addition of the 0.20 ml of potato rinse water the recorder was started and the cell immediately inserted into the spectrophotometer to enable a "progress curve" to be obtained for the enzyme.

The initial velocity was obtained by drawing a tangential line to the curve approximately 48 seconds after the reaction had begun. The enzyme activity was expressed as the change in absorbancy units/minute.

Method for "Tannin" Determination (hydroxylated aromatics)

The method followed was that found in "Standard Methods for the Examination of Water and Wastewater" (15). Although the results are reported as "tannin" they more properly should be referred to as "hydroxylated aromatic" compounds.

The standard used for the preparation of the standard curve was tannic acid and the wavelength used for analysis was 650 nm.

Carbon Treatment of Rinses 1-5 of Potato Rinse Water

French-fry slices were rinsed with tap water (solid:liquid ratio of 3:10). The rinse water was then centrifuged, filtered through glass-fibre filter paper (Whatman GL/C) and treated with either 0.10%, 0.30% or 0.50% dosages of "Aqua Nuchar" powdered carbon. The samples were placed on a rotary shaker at 300 rpm for 15 minutes to ensure maximum adsorption. The adsorption isotherm for tannin and enzyme (Figure 6) shows that carbon is a good adsorbent for these factors. Both factors can be reduced to low concentration levels. Samples were taken before and after treatment for analysis of "tannin" and enzyme activity. Carbon was removed from solution by filtration through glass-fibre filter paper. This "rinse and treat" combination was repeated for 5 rinses.

The object of this procedure was to obtain the minimum dose of powdered carbon that would effectively control enzyme activity and would remove "tannin-like" materials from solution. Incomplete removal of the enzyme would only lead to a gradual buildup of the enzyme in the water loop, which would soon bring about further browning as soon as fresh substrate contacted the enzyme.

From Figures 7(a) and 8(a) it can be seen that a dose of 0.10% is very effective in lowering both tannin and enzyme activity, but is not sufficient to prevent accumulation of both enzyme and substrate at each rinse stage. Although the carbon does produce "aesthetically" acceptable water at this level, i.e., there is little evidence of browning, this would be reversed rapidly at higher rinse stages when the recycled water came in contact with more substrate.

A level of 0.30% (Figures 7(b) and 8(b)) is much more effective in controlling both enzyme and substrate and the rate of increase of both parameters with increasing rinses is decreased.

At a level of 0.50% (Figures 7(c) and 8(c)) both parameters are almost static after the first rinse. The residual enzyme activity was not measurable up to and including the fifth rinse.

From the preceding work it can be seen that despite the fact that relatively small dosages of carbon are required to produce aesthetically acceptable water, relatively large dosages of carbon are required to limit the increase in enzyme activity with successive rinses.

Therefore, attention was given to other possible treatments that the rinse water might receive to halt the progress of the enzyme. Many substances have been used to inhibit the enzymatic browning of food products. Such substances include ascorbic acid, sodium bisulfite, sodium chloride, malic and citric acids.

There are advantages and disadvantages in the use of any of these compounds Some compounds such as ascorbic acid are not suited because of cost while others such as bisulfite can produce objectionable flavors and odors in the food product itself and additional wastewater problems. Citric acid was

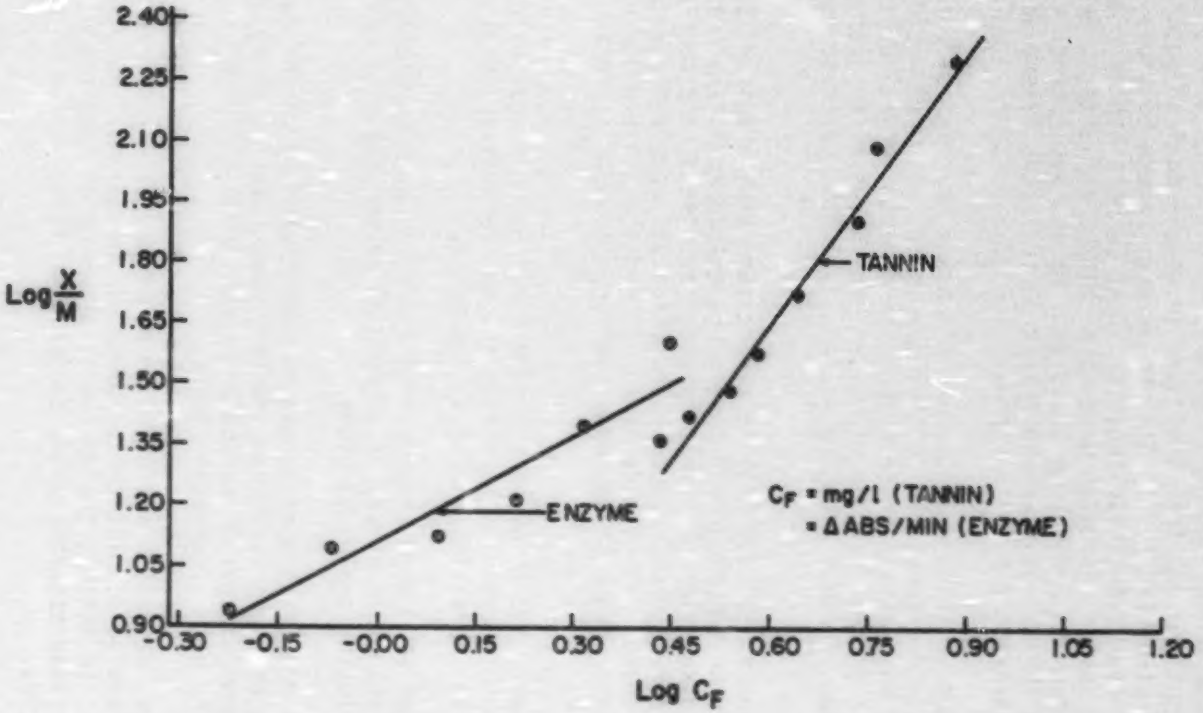


Figure 6. ADSORPTION ISOTHERM FOR TANNIN AND ENZYME REMOVAL

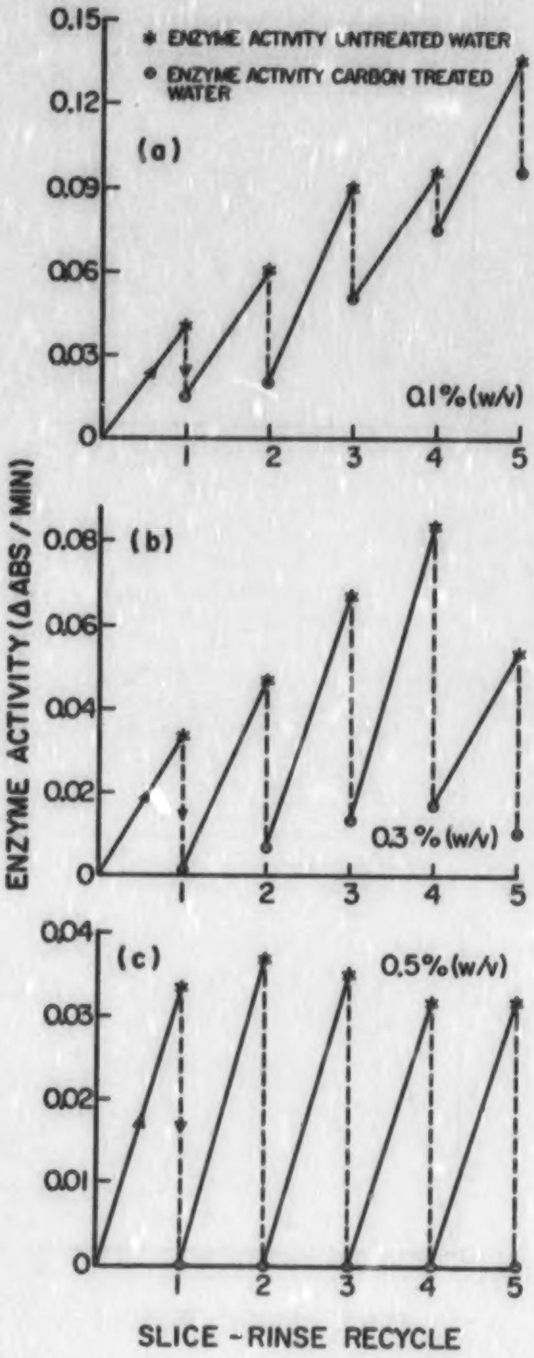


Figure 7. CONTROL OF ENZYME ACTIVITY BY ACTIVATED CARBON

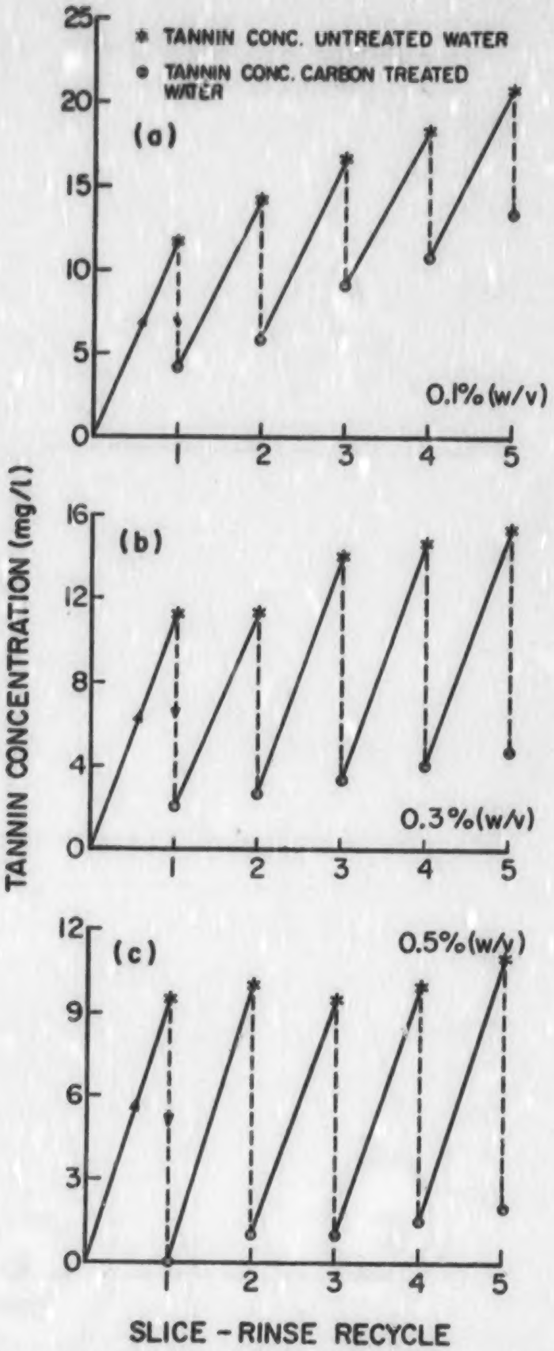


Figure 8. CONTROL OF TANNIN BY ACTIVATED CARBON

chosen mainly because of cost and its successful use as a constituent and additive in many food products.

Effect of pH on Enzyme Activity

French-fry slices were rinsed with water (water:solids ratio of 3:10) to produce a total volume of 1500 ml of rinse water. The water was recycled over fresh potato slices five times to achieve a fairly high level of enzyme activity. Samples of 100 ml of the final rinse water were adjusted in pH from 3-7. Following this adjustment the samples were dosed with 0.10 g of carbon and the enzyme activity determined on each sample. Residual activity of the enzyme was expressed as a percentage of the activity of the untreated rinse water at the fifth rinse. Results of this work can be seen in Figure 9. The enzyme was almost completely inactivated at a pH of 3, and at a pH of 5.5 only 16% of the original activity remained.

Thus by altering the pH it appears that most of the enzyme is inactivated, and at the same time the active portion of the enzyme which remains is severly inhibited by the lowered pH.

From the point of view of cost, it would appear that the pH of the rinse water should be maintained at a pH of between 5.0-5.5. An experiment where rinse water is "rinsed and treated" (pH adjusted to 5.5) is shown graphically in Figure 10. It is to be noted that the pH has little if any effect on the tannin concentration but that the enzyme activity is held constant when the pH is kept at 5.5.

The greatest dosage of acid required is in adjusting the pH of the original feed water. To adjust the pH of 500 ml of tap water to 5.0 required 0.25 ml of 1M citric acid. After each rinse only 1.1, 1.0, 0.35, 0.70 and 0.25 ml of 0.1M citric acid were required to maintain the pH at 5. Thus of the total acid added 67% was required to lower the pH of the original feed water.

Therefore the major cost of the use of citric acid would be in the initial dosing of the "start up" and "make up" water used in the process. The amount required at this stage would be dependent upon the buffer capacity of the water at any plant location.

As citric acid is an organic acid it may be argued that addition of such an acid would add considerably to the oxygen demand of the recycled water. Up to the 5th rinse stage pH adjustments from 4.5-5.5 in our series of experiments would add in theory between 100-340 mg/l to the chemical oxygen demand. However, in studies where potato rinse water (5th rinse) was adjusted to pH levels ranging from 4.5-6.75 and then dosed with up to 0.2% of powdered carbon, it can be seen from Figure 11 that, in fact, at the maximum dosage of carbon, samples lowered to a pH of either 5 or 5.5 had a slightly lower COD than the sample which was unadjusted. This result may be explained by the fact that the additional COD of the citric acid is compensated for by removal of slight amounts of protein which are denatured upon acid addition, and then removed in the filtration step.

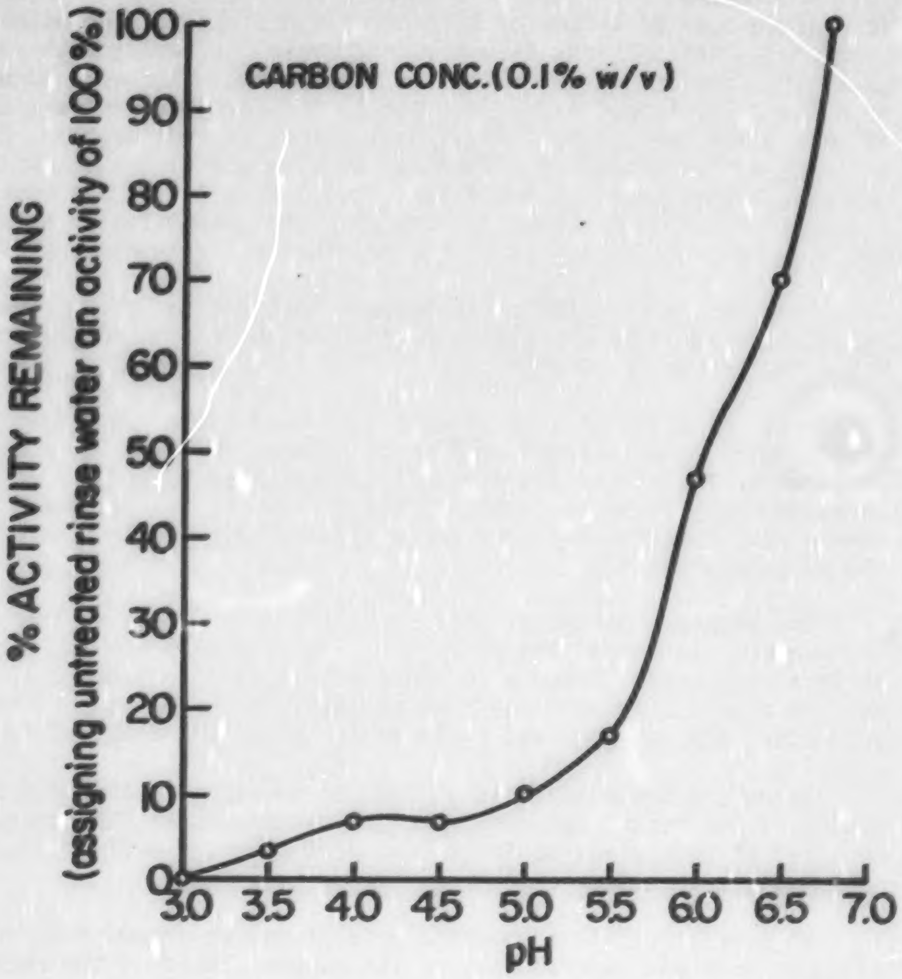


Figure 9. THE EFFECT OF ACTIVATED CARBON AND pH ON ENZYME ACTIVITY OF RECYCLED POTATO RINSE WATER.

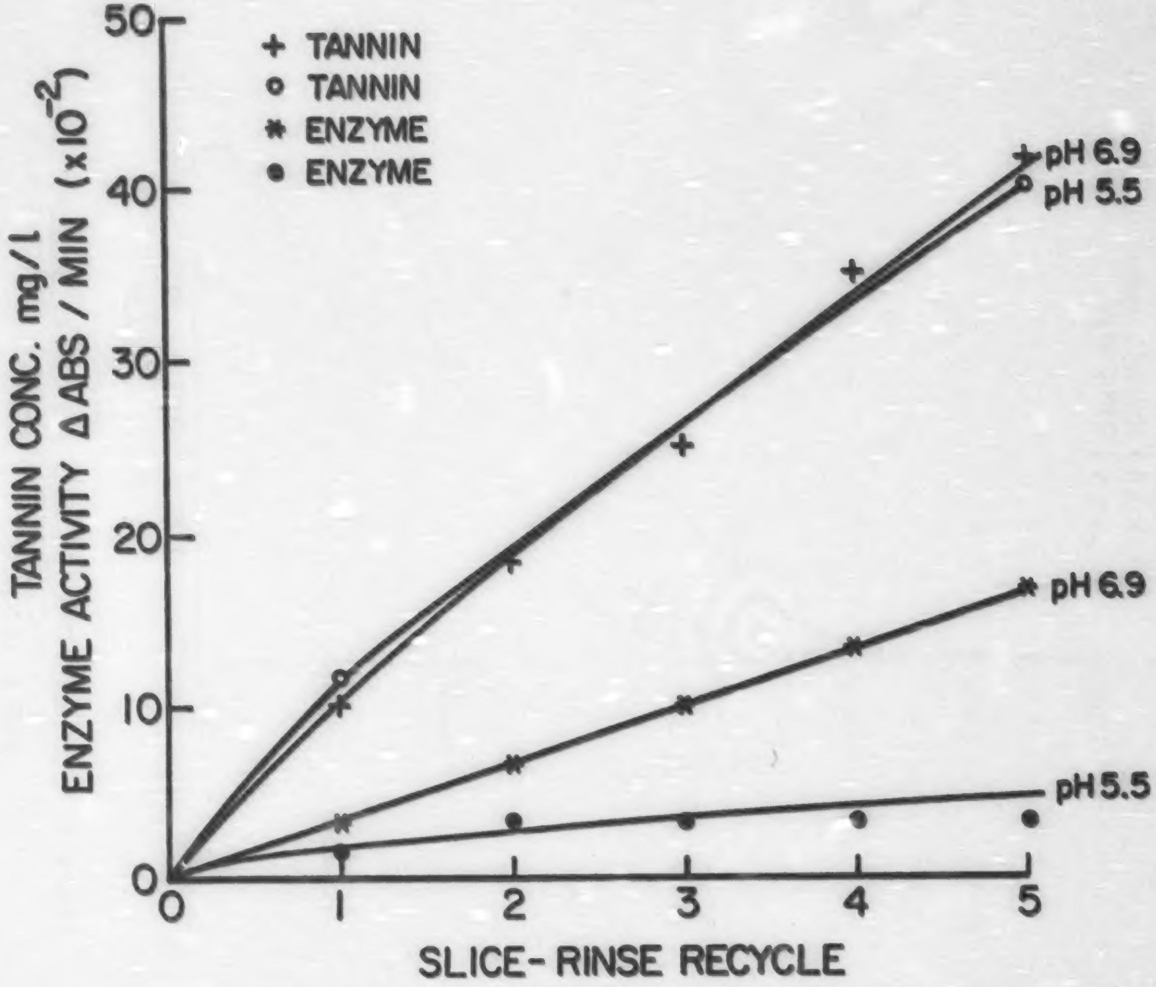


Figure 10. CONTROL OF COLOR FORMATION BY pH CONTROL

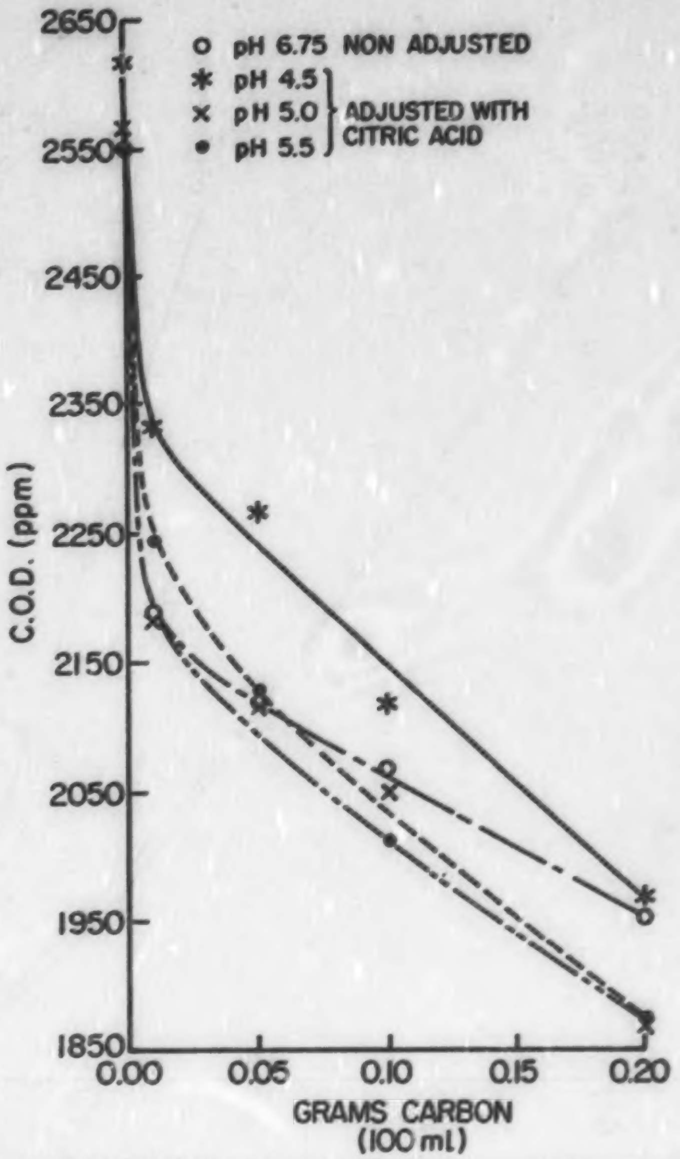


Figure 11. EFFECTS OF CITRIC ACID AND ACTIVATED CARBON ON THE CHEMICAL OXYGEN DEMAND OF RECYCLED RINSE WATER (5X).

CONCLUSIONS

The work to date at the Food Science Department, based on a complete closed-loop recycling system, has been performed only on a laboratory scale. To evaluate the economics of the process it would be necessary to simulate actual plant conditions by scaling the design to at least a pilot plant stage. It has been demonstrated in other studies that starch recovery systems can be a profitable venture to the potato industry. The cost of a carbon design system on a plant scale, needs to be evaluated. As part of the total system concept, activated carbon could be produced on site from "waste organic solids" of the industry, or from farms (e.g. straw, cobs), or from urban areas (e.g. newspapers). We have used these materials for about a decade for these purposes. Commercially powdered activated carbon sells for as little as 9 cents per pound (1973 data) (16) and regeneration shows a cost reduction of up to 70% from the cost of continuously replenishing powdered carbon. On the laboratory scale, carbon costing cannot be accurately evaluated because of scale-up variables such as clean water make-up.

As indicated in the report a combination treatment of pH and carbon may also prove to be beneficial. Control of enzyme activity by chemical means alone is not recommended for the closed loop recycling system. Activated carbon is felt to be an essential ingredient in the control of color. Carbon at the same time removes other factors such as COD, odor, and foam. Studies in our laboratory have shown that carbon is also effective in controlling the possible bacterial build-up that could occur with continuous reuse, as predicted by Figure 3.

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THE TOXICITY OF FOOD PROCESSING EFFLUENTS TO FISH

by

D.W. Bissett*

Whenever the word "toxicity" is used to describe the effects of a certain material on some area of the environment, an alarm mechanism sound in most people's minds. The word "toxic" is synonymous with "poisonous" or at minimum, "harmful". In this context then, the Environmental Protection Service of Environment Canada has incorporated toxicity testing of effluents into its regulation development program to control the harmful effects of these effluents to the aquatic environment and in particular, fish.

One might well ask the question, "Why emphasize fish toxicity testing in developing water pollution control regulations?" Indeed this is a valid question as most effluent regulations usually specify relatively common parameters such as BOD, suspended solids, ammonia nitrogen, phosphate or pH.

In the United States, the enabling legislation with regard to water pollution is the Federal Water Pollution Control Act passed in 1972. This legislation was specifically designed to control water pollution by the setting of standards respecting levels of point discharges to navigable waters.

In Canada, there are a number of legislative documents relating to water and water pollution in general. However only one Act, the FISHERIES ACT, authorizes the Governor in Council to set regulations respecting the deposit of deleterious substances into waters frequented by fish. This act was originally passed in 1868 for the protection of the Canadian fishery resource and indeed, a number of sections deal with provincial rights to licence, distance of nets from one another, possession or sale of fish, etc. Only in 1971 when Environment Canada was organized from a number of other federal departments, was the act amended to permit the establishment of regulations limiting the discharge of substances which are harmful to fish or to the use of fish by man.

In order to establish regulations for specific industrial discharges under the Fisheries Act, it is absolutely essential to evaluate the effects of industrial wastewater effluents on fish. For each industrial sector, a rather extensive programme of toxicity testing is carried out to determine how acutely lethal effluents are and how effective existing treatment methods are in removing toxicity. This paper describes in general the toxicity testing methodology employed by EPS laboratories located across Canada and in particular results which have been obtained for food processing effluents.

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*D.W. Bissett, Water Pollution Control Directorate, Environmental Protection Service, Environment Canada, Ottawa, Canada

What Does Toxicity Testing Involve?

In its crudest form, a fish toxicity test simply involves taking a bucket of effluent, throwing in some fish and observing the results. No doubt, the most extreme effect would be death, but one would not know if the mortality was due only to a lack of oxygen available to the fish or to some other toxic component in the effluent.

Before discussing the actual fish bioassay procedures in detail, a general introduction of the terminology and techniques would be relevant. The four most common terms used to describe toxic effects (1) are as follows:

acute - response occurs rapidly, usually within four days

chronic - involves a response which is lingering or occurs over a long period of time

lethal - causes death or sufficient to cause it

sublethal - below the level which directly causes death

As a first assessment of industrial effluents, EPS has been looking at acute lethal toxicity: that which causes mortality in a short period of time. Lethal toxicity is usually expressed in terms of an LC50 (similar terms are TL50 or TLM), which is the concentration lethal to 50 percent of the fish over a specific time interval. A more detailed account of toxicity measurements can be found in Sprague's "The ABC's of Pollutant Bioassay Using Fish"(3).

While a variety of test methodologies exist for evaluation of toxic effects,(1) the bioassay procedures for determination of an LC50 have been well defined (2,3) and involve the following:

1) a series of test vessels, each with a different but constant concentration

2) a group of similar fish in each container

3) observations of fish mortality at regular exposure times for the duration of the test period

4) calculation of the LC50 results expressed as a concentration which causes mortality to 50% of the fish

Toxicity tests can be conducted in a static, semi-static or continuous flow (flow-through) mode. In the static test, the fish are placed in a container of standing test water for the duration of the test whereas in the semi-static mode, at regular intervals (eg. 12 or 24 hours) the same group of fish are exposed to a fresh test solution. In the continuous flow test, the fish are subjected to a test solution which is continually renewed. Each method has its several advantages. In the main, the static test is less expensive and time consuming whereas the continuous flow test is generally more sensitive if carried out properly.

Specific test conditions may vary according to the laboratory or type of effluent being examined. Some of the more important items which have become standardized in EPS testing programs are as follows:

1) The standard test fish species is rainbow trout (Salmo gairdneri Richardson)

2) Variation in fish size is controlled within the test and limited to less than 10 grams.

3) The fish are acclimatized and maintained in holding facilities at water temperature of 15°C±2°C. Tests are conducted at 15°C±1°C.

4) Dilution water for holding and testing must be dependable, clean and obviously non-toxic.

5) The volume of test solution must be sufficient so that the fish will not deplete any toxic constituents by uptake (usually 1.5 - 2 litres per gram of fish per day).

6) Aeration of the test solution should provide a minimum dissolved oxygen of 8 mg/l.

7) The pH of the test solution should not be directly adjusted.

Selection of the concentrations of effluent to be used in the toxicity test is another important part of the testing. For preliminary or exploratory testing, the span of concentrations should not be very restrictive. Once the general range is determined the span can perhaps be narrowed but it should always be sufficiently wide to cause from zero mortality to complete mortality at either end of the range. With food processing effluents, unless the effluent is consistently non-lethal, test solutions should cover the full range from control or no effluent to undiluted effluent. Most commonly, a geometric or logarithmic series using concentrations such as 100, 56, 32, 18, 10 percent effluent by volume, is employed.

Analysis of Test Results

Prior to a discussion of the results from various food processing sectors, a brief outline of the method of calculation of LC50 values is useful. The laboratory results of a typical toxicity test are presented in Table 1. Fish mortalities for the 5 test concentrations plus control were observed over a 96 hour period. Two of the major parameters which should be monitored at regular intervals throughout the test are dissolved oxygen and pH. Note the low initial dissolved oxygen concentration in the undiluted effluent, a typical occurrence with untreated or partially treated food processing effluents.

Determination of the time period where all observable responses occur may aid in the identification of possible causes of mortality and perhaps in future work allow the duration of the test to be shortened.

TABLE 1

TYPICAL TOXICITY TEST RESULTS

CONCENTRATION % BY VOLUME	DISSOLVED OXYGEN mg/1	INITIAL pH	% MORTALITY at (HOURS)									
			¼	½	1	2	4	8	24	48	72	96
100	3.8-9.5	8.6	0	0	0	0	0	10	80	100	100	100
56	6.3-9.4	8.45	0	0	0	0	0	0	0	0	80	90
32	7.0-9.2	8.1	0	0	0	0	0	0	0	0	20	40
18	7.6-10.0	7.85	0	0	0	0	0	0	0	0	0	10
10	8.4-10.6	7.7	0	0	0	0	0	0	0	0	0	0
CONTROL	8.4-10.8	7.7	0	0	0	0	0	0	0	0	0	0

The results of Table 1 indicate that mortalities occurred over the entire 96 hour test period for various concentrations of effluent. Frequently, with food processing effluents, all mortality will occur within the first 24 hour period, although with some meat packing effluents, mortality has only begun to occur after 72 hours exposure to undiluted effluent. Unfortunately, most EPS laboratories presently lack facilities and staff necessary for the exact determination of the toxic constituents responsible for the death of the fish.

A number of methods of calculation of the LC50 value exist,(3) probably the most common being the graphical determination after Litchfield and Wilcoxon(4). This method involves plotting the dose (or concentration by volume) against the percent effect (mortality) on logarithmic - probability paper, as shown in Figure 1 for the previous results. Note that 0 and 100 percent effects are not accommodated on the graph paper and are thus indicated with an arrow. A straight line is fitted to the points by eye, placing most emphasis on the results where partial mortality was observed and minimizing the total vertical distance between the points and the line. The LC50 value is the concentration where a 50 percent mortality effect occurs, in this case 34 percent effluent by volume.

The method of Litchfield and Wilcoxon allows the determination of the slope of the line and confidence limits and provides a means for approximating the confidence limits of effects other than the median or 50 percent effect, the details of which will not be presented here.

Toxicity Tests Of Food Processing Effluents

The results of toxicity testing of food processing effluents have been summarized for the following industrial sectors:

a) Potato Processing

b) Meat and Poultry Products

c) Dairy Products

d) Fruit and Vegetable Processing

e) Associated Industries

EPS surveys have mainly been directed towards plants utilizing some form of biological treatment as these plants would, if designed and operated properly, produce effluents with acceptable water quality parameters such as BOD or suspended solids.

Rather than discuss the results of each plant in detail, the major emphasis will be directed to those end-of-pipe treatment processes that produce non-acutely lethal effluents and to possible causes of toxicity at other plants.

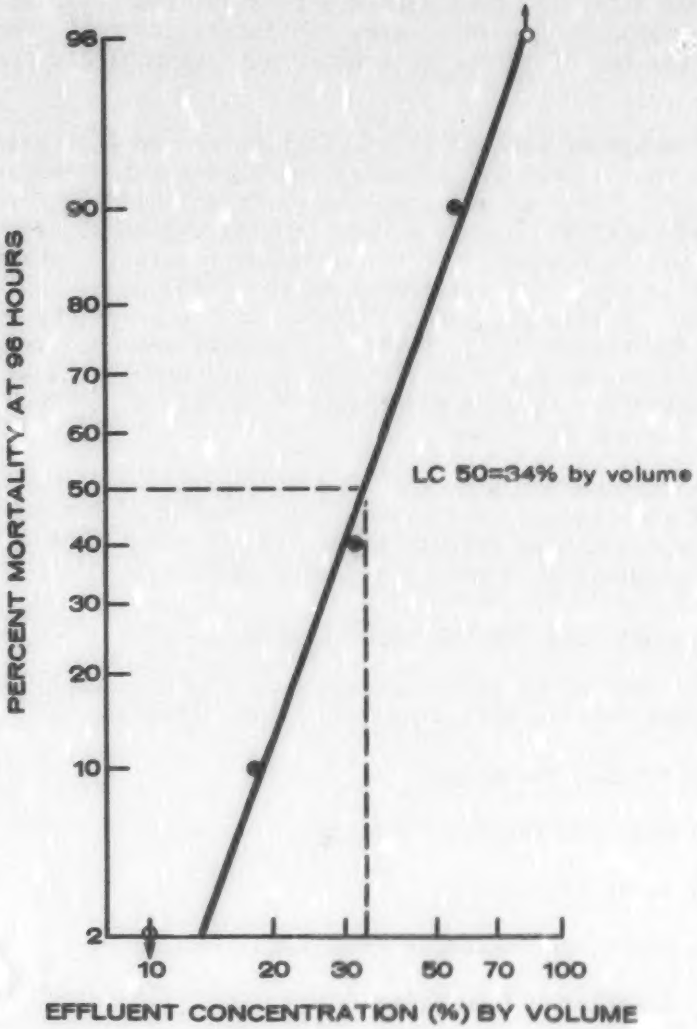

FIGURE 1 PLOT OF TOXICITY TEST RESULTS ON LOG-PROBABILITY

a) Potato Processing

Three potato processing plants in Canada presently employ secondary biological treatment systems. The results of surveys at these plants as well as several other operations are presented in Table 2.

Plant B employs two aerated lagoons in series, with approximately 10 and 25 day retention times respectively. Due perhaps to some non-biodegradable residue, toxicity tests have usually resulted in complete mortality with full-strength effluent while producing no mortality in an 80 percent by volume dilution.

The french fry operation (plant A) employing two plastic-media trickling filters in series has been the subject of considerable study in the last two years. Although BOD and suspended solids removals are acceptable, the final effluent has always exhibited a lower lethal concentration than screened effluent. To date, no specific cause for this phenomenon has been found, except that suppression of certain components such as ammonia and suspended solids has not resulted in reduced toxicity. A study into possible toxic chemical residuals is continuing.

Potato chip operations which employ pretreatment such as screening discharge effluents which are extremely toxic having LC50 values ranging from 12-44 percent.

b) Meat and Poultry Products

The data presented in Table 3 summarizes the results of an extensive survey of meat and poultry packing plants and rendering operations across Canada.

Perhaps the most important observation to be made is that aerobic biological treatment systems such as extended aeration activated sludge (Plants E and H) and oxidation ditch (Plant D) in all cases produced effluents exhibiting no mortality to fish.

Where anaerobic/aerobic lagoons or stabilization ponds were evaluated, on only one occasion (plant E) did no mortality occur in the treated effluents. Indeed, in two cases (Plant B and F) the effluent following treatment was at least as toxic as the raw waste thought to be due in most part to the high ammonia concentrations generated in the anaerobic degradation of protein material.

Although ammonia has not been identified as being the sole component responsible for acute lethal toxicity, there is an apparent relationship between the ammonia concentration in an effluent and the resulting LC50 value as shown by the data presented in Table 3. The systems which produce non-lethal effluents are those which have the capability to nitrify ammonia to the nitrate form.

c) Dairy Products

Evaluation of the effluents from dairy products plants has been carried out under both summer and winter climatic conditions as shown in Table 4. Values

TABLE 2

POTATO PROCESSING PLANTS

PLANT & PRODUCT	TREATMENT	EFFLUENT SAMPLE	BOD mg/1	TSS mg/1	NH_3-N mg/1	LC 50 %
A FRENCH FRIES	TRICKLING FILTER	SCREENED	2050	1745	4.7	32-56
		FINAL	115	89	12.3	18-32
B FRENCH FRIES	TWO AERATED LAGOONS	SCREENED	1735	-	5.4	50-100
		FINAL	100	-	5.5	85-100
C FRENCH FRY AND DEHYDRATED PRODUCTS	EXT. AERATION & 3 LAGOONS	SCREENED	1385	560	44	25-50
		SEC. CLAR.	9	10	2.9	ND
		FINAL	<10	5	0.8	ND
D FRENCH FRY	NO TREATMENT	RAW	1700	2480	(pH-11.8)	13.5
POTATO CHIPS (SEVERAL PLANTS)	SCREENING	SCREENED	590-2100	600-1760	9.3-70.3	12-44

ND - NO MORTALITY IN FULL-STRENGTH EFFLUENT

TABLE 3

MEAT AND POULTRY PRODUCTS PLANTS

PLANT & PRODUCT	TREATMENT	EFFLUENT SAMPLE	BOD mg/1	TSS mg/1	NH_3-N mg/1	LC 50 %
A RENDERING PLANT	STABILIZATION LAGOONS (2)	RAW	4419	-	215	6.25
		FINAL	12	-	19.5	50-100
B RENDERING PLANT	ANAEROBIC/ AEROBIC LAGOONS	RAW	975	272	77.7	20-30
		FINAL	85	164	85.0	10-20
C MEAT-PACKING PLANT	AIR FLOTATION (CHEMICAL ADDITION)	RAW	968	825	17.8	30-40
		FINAL	348	186	17.7	90-100
D MEAT-PACKING PLANT	OXIDATION DITCH	RAW	1065	693	23	37-45
		FINAL	<20	15	<0.25	ND
E MEAT-PACKING PLANT (SMALL)	ANAEROBIC AEROBIC LAGOONS	RAW	1900	1300	195-145	16
		FINAL	350-650	155-90	1-10	ND-71
F POULTRY PACKING PLANT	STABILIZATION POND	RAW	1550	200	35	32-41
		FINAL	1200	130	75	32
G POULTRY PACKING PLANT	EXT. AERATION PHOS. REMOVAL	RAW	1675	325	65	25-71
		FINAL	400	150	<4	ND
H POULTRY PACKING PLANT	EXTENDED AERATION	RAW	485-900	130-400	34-44	12-50
		FINAL	<10-100	20-100	1-14	ND

TABLE 4

DAIRY PRODUCTS PLANTS

PLANT & PRODUCT	TREATMENT	EFFLUENT SAMPLE	BOD mg/l	TSS mg/l	LC 50 %	
					Winter	Summer
A Cheese &	AERATED	RAW	1600	200(500)*	14-40	9-12
Milk Powder	LAGOONS (3)	FINAL	550(67)	130	32-50	29-53
B Process	AERATED	RAW	1700	400-1900	14-24	<6
Cheese	LAGOONS (3)	FINAL	400(30)	150	32	ND
C Ice-Cream	EXTENDED	RAW	1000(6400)	2000(5000)	60	<3
	AERATION	FINAL	325(<15)	1800**(100)	ND	95-ND
D Butter &	EXTENDED	RAW	1800(600)	375	32-71	35
Milk Power	AERATION	FINAL	900(15-218)	2500**(25-1100)	50-100	ND-35
E Butter &	OXIDATION	RAW	1340(700)	980(650)	6-71	14-19
Milk Powder	DITCH	FINAL	<10	30	ND	ND

*Values in brackets indicate results obtained under summer conditions
**Bulking sludge at these plants

for BOD and total suspended solids obtained in the summer sampling survey are indicated in brackets where there was an appreciable difference from the results of winter survey. In general there was some difference in effluent quality parameters throughout the year although no definite relationships could be developed between toxicity and BOD or suspended solids.

Problems with the lagoon systems freezing over in the winter, resulting in partially anaerobic conditions and generation of hydrogen supphide, caused mortality to occur in these systems. In fact, even in summer conditions the effluent from Plant A exhibited toxicity due in part to a lack of sufficient aeration capacity in the third lagoon.

The extended aeration systems were capable of producing a non-lethal effluent provided that the "bulking" condition at these plants could be controlled. Overloading of the systems and a high C:N ratio have been cited as possible causes of the bulking problem.

The oxidation ditch at Plant E was the most stable system tested . At no time have any fish died when exposed to undiluted treated effluent. Even during the winter season, there was never any fish mortality and other effluent quality parameters remained consistent at less than 10 mg/l BOD and 30 mg/l total suspended solids.

Results of the dairy sampling program indicate that properly designed and operated systems are capable of producing effluents exhibiting no acute lethal toxicity.

d) Fruit and Vegetable Processing

The data presented in Table 5 were obtained in a survey carried out during the 1975 processing season.

For all commodities with the exception of Plant E producing fruit juices and concentrates, the screened wastewater was acutely lethal due to a number of factors in combination such as high oxygen demand and extreme pH. For example, effluents from plants B and F had a pH ranging from 4.6 to 5.3 whereas plant G had a pH of 9.6 to 9.8 when tested.

Most of the treatment systems examined were capable of producing effluents which exhibited no acute lethal toxicity to fish. However, problems were encountered at Plant C which employs an aerated lagoon prior to discharge to a municipal sewer. This aerated lagoon system was not well operated, being overloaded organically and lacking in sufficient nutrients, thus resulting in a "bulking" sludge.

e) Associated Industries

Preliminary surveys were carried out at several other plants associated with the food industry during the winter and spring of 1975, the results of which are summarized in Table 6.

Although the treatment efficiency of these systems was not exceptional (i.e. BOD removal ranging from 50 to 58 percent), the treated effluents with one exception did not exibit acute lethal toxicity.

TABLE 5

FRUIT AND VEGETABLE PROCESSING INDUSTRY

PLANT AND PRODUCT	TREATMENT	EFFLUENT SAMPLE	BOD mg/l	TSS mg/l	LC 50 %
A Canned Fruit	SOIL BIOFILTRATION	FINAL	980-1500	90-157	ND
B Pie Fillings, Jams, Jellies	AERATED LAGOON	SCREENED FINAL	1008-2880 158-296	128-178 31-42	24-27 ND
C Canned Vegetables (corn)	AERATED LAGOON	FINAL	415-864	1740-3250	71-100
D Canned & Frozen (corn, Broccoli, plums)	OXIDATION DITCH	SCREENED FINAL	1182-5100 1145-1685	310-580 240-370	13-17 ND
E Fruit Juices & Concentrates	EXTENDED AERATION	SCREENED FINAL	800-1300 15-95	26-350 15-63	ND ND
F Canned Tomatoes	SOIL BIOFILTRATION	SCREENED FINAL	500-5000 80-375	160-675 20-55	12.5-18 50-ND
G Tomatoes Products	EXTENDED AERATION	SCREENED FINAL	500-600 5-19	290-365 6-19	13.5-36 ND

TABLE 6

ASSOCIATED INDUSTRIES

PLANT AND PRODUCT	TREATMENT	EFFLUENT SAMPLE	BOD mg/1	TSS mg/1	LC 50 %
A Distillery (whisky, gin, Alcohol)	EXTENDED AERATION	RAW FINAL	800 340	58 12	50-100 ND
B Brewery	EXTENDED AERATION	RAW FINAL	1640 812	1505 260	28-71 ≈100
C Starch (corn) Products	TWO-STAGE ACT. SLUDGE	RAW FINAL	1475 630	2000 280	50-77 4-22
D Coffee, hot choc., instant tea, etc.	ACT. SLUDGE & POLISHING POND	RAW FINAL	1250 550	410 36	>100 ND

Perhaps of most concern in this preliminary survey were the results from Plant C, the starch products plant. The effluent, following treatment in a two-stage activated sludge system, is acutely lethal to fish having a 96 hour LC50 value between 4 and 22 percent by volume. The exact cause for the rather poor waste treatment efficiency and the extreme toxicity, has not yet been determined but may relate to the by-products generated in the degradation of corn starch process effluents.

Application of Toxicity Test Results

As noted earlier, environmental regulations for the control of discharges of deleterious substances are developed under the Fisheries Act. Generally, the regulations allow the discharge of quantities of certain substances based on the levels achievable by best practicable process and treatment technology (BPT) for a particular industry sector. In addition, where BPT demonstrates that an effluent quality which exhibits no acute lethal toxicity can be achieved, then a toxicity requirement can be established as a "catch-all", thus reducing the number of regulated parameters.

As shown in Table 3 for the Meat and Poultry Products industry several plants employed treatment systems which discharged effluents having no fish mortality. Since these systems were identified as exemplifying BPT for the industry, an objective is proposed wherein a minimum of 50 percent of the test fish must survive for 96 hours in the undiluted effluent. A similar objective has been proposed for the Potato Processing industry, based mainly on the results of plant C.

Given that the possibility exists for some fish to die of natural causes in the testing procedures, a requirement of 50 percent survival is considered consistent with effluent quality obtained from current BPT systems. Also, environmental consultants can not guarantee that biological treatment systems will always discharge an effluent in which no fish mortality will occur.

The regulatory test procedure used to determine whether a plant meets the objective will be the 96 hour continuous flow test incorporating the conditions outlined in a previous section. A more simplified static bioassay procedure may be used by the plants to monitor the toxicity of their effluents at regular intervals.

Regulations incorporating these toxicity objectives as guidelines have now been drafted for the Potato Processing Industry and Meat and Poultry Products Plants. Effectively, these regulations and guidelines will come into force by mid 1976. To follow are regulations for the Dairy Products industry in 1977 and the Fruit and Vegetable Processing industry in early 1978.

SUMMARY

The testing of food processing effluents with respect to their toxicity to fish is relatively new and not reaily understood in the industry. Consequently many plants managers have shown some concern when approached on this subject.

The objective of this paper has been to provide some insight into the aspects of fish toxicity as it relates to the food processing effluents.

In summary then, the following points should be noted:

1) Government agencies will continue to monitor the multiple effects of industrial discharges on the aquatic environment.

2) The major causes of fish toxicity from food processing effluents are organic material exerting a high oxygen demand, cleaning and disinfecting agents, and by-products such as ammonia and hydrogen sulphide generated in the degradation of certain waste constituents.

3) Properly designed and well-operated biological treatment systems are capable of producing an effluent quality where acute lethal toxicity is not observed.

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CHARACTERIZATION AND POTENTIAL METHODS FOR REDUCING WASTEWATER

D. L. Grothman*, L. J. P. Scully**, P. M. Berthouex***, D. O. Dencker****

INTRODUCTION

The purpose of this project was to determine the wasteload from different hog slaughtering processes, to characterize the waste streams, and to make changes in processes and equipment in order to achieve one or more of the following objectives without reducing hog kill capacity or the quality of the carcasses produced:

1. Reduce water use
2. Reduce and/or prevent product loss to sewers, and
3. Reuse wastewater where possible

It has long been apparent to those in the meat packing industry that there is great potential for reduction of wasteload to the sewers through equipment, process, and procedural changes. However, most emphasis has been placed towards efficient end-of-pipe wastewater treatment.

Many in-plant waste reduction measures can be designed into new plants, but in implementation older facilities present numberous problems. Also, new equipment should be designed with water conservation and waste generation in mind.

DESCRIPTION OF PLANTS

The majority of this study was done at the Madison plant of Oscar Mayer & Co. with a few processes studied separately at the Davenport, Iowa, or Beardstown, Illinois, plants.

The Madison plant includes a modern meat processing plant, spice processing, and plastic film production areas as well as a hog kill rated at 1,000 head/hour and an 80 head/hour beef kill. The facility includes edible and inedible rendering. The plant's power house supplies all of its steam and about 80% of its electrical power. Seventy-five percent of the water used is from the

*Project Engineer; Oscar Mayer & Co., Madison, Wisconsin.
**Peat, Warwick & Mitchell; Washington, D.C.; formerly Research Assistant; Water Resources Center; University of Wisconsin, Madison, Wisconsin.
***Associate Professor; Department of Civil and Environmental Engineering; University of Wisconsin, Madison, Wisconsin.
****General Sanitary Engineer; Oscar Mayer & Co., Madison, Wisconsin.

Company's own wells. Wastewater at this plant is segregated. Clear water drainage from roofs and parking lots, water used for cooling plastic extruders, etc., is discharged to the city storm sewers. Sanitary sewage discharges directly to the Madison Sewerage System. Manure water (wastewater from the stockyards, stomach dumper, dehairing machine, and scald tank) is screened to remove the large solids, settled to remove grit, and pumped to an Oscar Mayer & Co. operated wastewater treatment site for biological treatment. The plant greasewater system collects the wastewater from all of the floor drains and processes throughout the entire plant. Greasewater is separately treated by settling and dissolved air flotation, and is then combined with the manure water for biological treatment (two stage trickling filter).

The effluent from biological treatment is discharged to a Madison Metropolitan Sewerage District interceptor sewer. Sludge is dewatered by vacuum filter.

Madison also has a blood collection system on the kill floor which feeds a blood recovery system. This is a part of a dual drainage system. During production the blood drains are open for recovery of blood. When clean-up starts, the blood drains are plugged and the greasewater drains are opened.

The Davenport plant includes a meat processing plant, complete edible and inedible rendering, and a hog kill capable of processing 750 head/hour. Davenport has its own power plant to supply steam and electricity. Wells on the property supply 80% of the water used in the plant. Wastewater is segregated in Davenport as in Madison except for a few roof drains which flow into the greasewater drainage system. The manure water drainage system collects water from the stockyards, scald tank, dehairing machine and stomach dumper and sends it across the rotostrainer which removes the large solids. From the rotostrainers the wastewater discharges to a city sewer. The greasewater drainage from floor drains throughout the plant flows across two rotostrainers to remove the solids and then through a dissolved air flotation tank before discharging to a city sewer.

Beardstown was built in 1967 as a hog slaughtering and butchering facility with a capacity of 750 hogs/hour. Since then, the plant has been increased in size by 40% to provide additional room for ham canning and other operations. The plant also has edible and inedible rendering. All water comes from wells located on the property. All plant wastewater except clear water from roof and yard drains is treated by screening and flotation before being pumped into anaerobic, intermediate aerobic and final aerobic lagoons in series.

SLAUGHTERING PROCESSES

The process described is used in the Madison plant.

The hogs are anesthetized in a conveyorized carbon dioxide chamber. Unconscious hogs are discharged onto an inclined steel-slat conveyor which has a stainless steel collection trough along one side. The hogs are arranged on the conveyor so their necks are over this trough and their carotid arteries and jugular veins are severed with a knife. The blood is collected and pumped to a blood processing area where it is coagulated and dried for use as an animal feed supplement.

The carcasses drop from the bleed conveyor into a long shallow scald tank which is filled with 140°F water to which lime has been added. The carcasses are moved through the tank by mechanical "dunkers" which submerge the carcass and push them through the tank. Total scald time is about five minutes. The carcasses move out of the scald tank into a "Boss" dehairing machine. Hot water showers lubricate the carcasses to prevent the dehairing paddles from tearing the hide and flush away removed hair and toenails. The dehaired carcass is gambreled---a worker slits the hind legs and inserts a steel bar, the gambrel, behind the achilles tendons. The gambrel is hung on the steel trolley which is pulled by a chain along an elevated rail to transport the hanging hog through the rest of the process.

The carcasses are dipped into a tank containing 290°F rosin which covers all of the carcass except the last eight inches of the hind legs. The carcass is showered lightly to harden the rosin and the rosin is then stripped off by machine and by hand. This removes hair not removed in the dehairing machine. The carcass is conveyed through a singer where very fine hairs are burned off. A set of rubber paddles strip off burned residues while the carcass is lubricated with a water spray in the rail polisher. Tissue is cut from between the toes and the carcasses are manually scraped with knives to remove or loosen remaining soil. A final carcass shower rinses the carcass with large quantities of water. Once the carcass has passed this point, any remaining soil or hair must be removed by excision.

Disassembly of the carcass starts with removal of eyelids along with the surrounding skin and fat. The neck is almost completely severed so the head is left hanging by a strip of skin along the jaw. USDA Insepctors slash open the salivary glands to check for abscesses and they examine the outside of the carcass for dirt, bruises, or signs of disease. The sternum (brisket) is split, the aitch bone is split, and the bladder and uterus (pizzles and piggy bags) are removed. The anus (bung) is cut around and freed from the surrounding tissue. Viscera (heart, lungs, liver, stomach, pancreas and intestines) are removed and placed in an examination pan which travels by conveyor alongside the carcass. The carcass is split into halves by sawing through the backbone. Pieces of the dorsal abdominal aorta are trimmed out and the stick wound in the neck is slashed open. The urethra (male pigs) is removed. The membrane over the kidneys is slashed open and the kidneys are slid out for examination. A final examination internally and externally for bruises, cuts, dirt, etc. is made and any unsatisfactory parts are trimmed off. The kidneys are removed either to be washed, boxed and frozen for animal feed or to be sent to inedible rendering. The head is washed, removed and butchered (muscles from the cheeks, scalp and tongue are saved; the head is split and the pituitary gland and hypothalmus are removed for pharmaceutical purposes; and the skull and jaw are ground up and sent to inedible rendering). Leaf fat which lines the interior dorsal area of the carcass is pulled out and sent to lard rendering. Loose fat and tissue is scraped from the interior of the carcass. The stick wound on the neck is washed. Interior carcass fat is trimmed a little more, then the carcass is weighed and sent to be chilled overnight before being butchered.

The entire kill process is graphically shown on Figure 1.

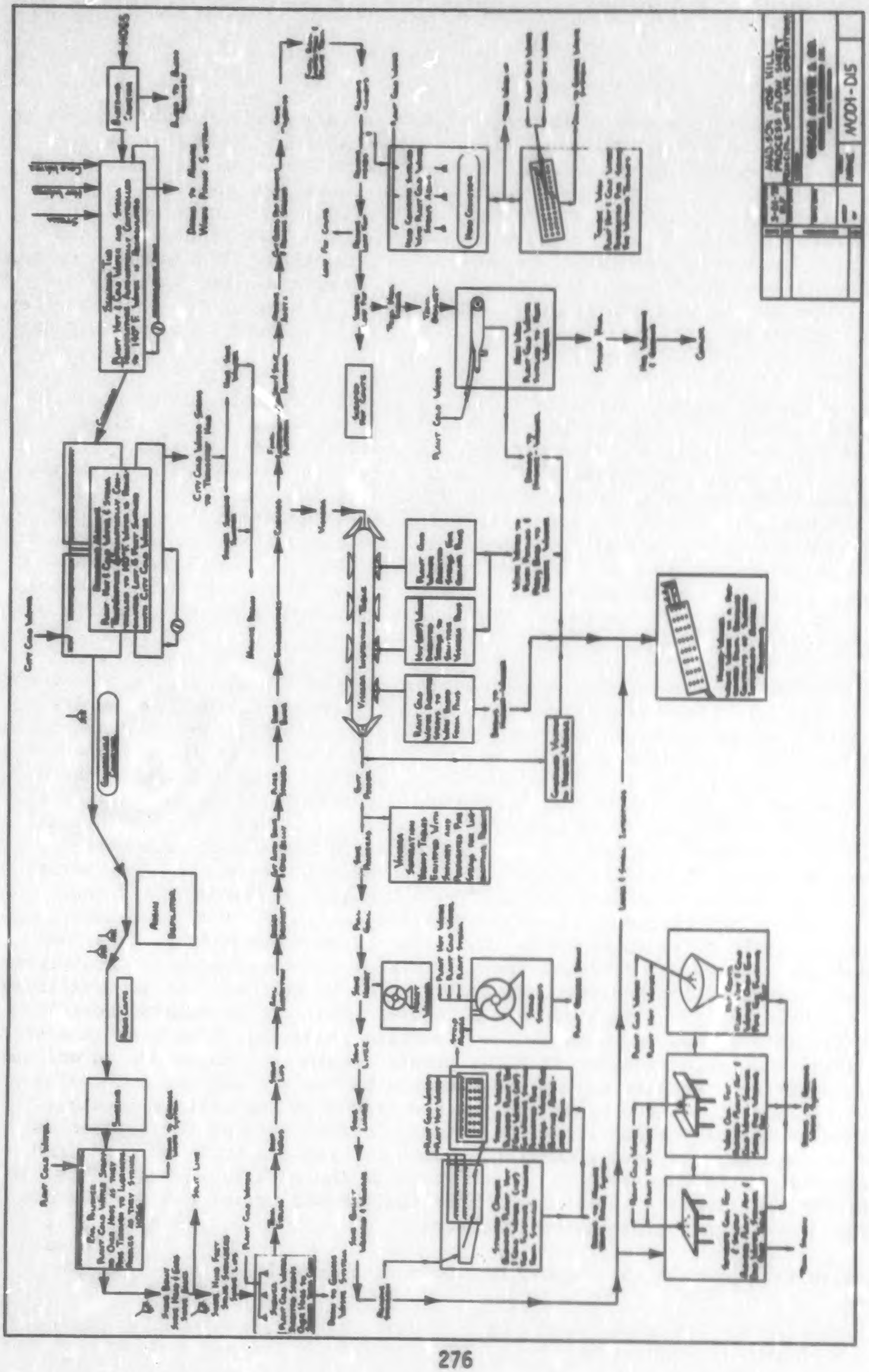
HOGS
HOG KILL
PROCESS FLOW SHEET
MOD1-DIS

Figure 1. Madison Hog Kill Process Flow Sheet.

The removed viscera is checked by USDA Inspectors for signs of disease. Diseased viscera is sent to inedible rendering. Acceptable viscera is separated for further processing:

1. The heart is slashed open, to remove the blood clots, chilled, and held for use in processed meats.
2. The lungs are frozen for animal food or rendered in inedible rendering.
3. The stomach is slit open so contents can be flushed out, and tumble washed. The mucosa is removed for pharmaceutical processing and the remainder of the stomach is washed, scalded and frozen for animal food.
4. The caul fat (omentum) is removed, washed and sent to lard rendering.
5. The liver is trimmed and chilled for use in processed meats.
6. The gall bladder goes to inedible rendering.
7. The large and small intestines, condemned viscera and pizzle and piggy bags are sluiced to the hasher-washer where they are slashed open and washed by the sluice water. The washed solids go to inedible rendering.

SAMPLE COLLECTION AND ANALYSIS

Quantifying the water use and discharge of pollutants from the kill floor is difficult in any plant because the water supply and the drainage pattern is never simple and it is usually impossible to isolate each process from its neighbors. The methods used to overcome this problem in characterizing the Madison hog kill operation will be summarized here briefly. A variety of methods including water meters, a bucket and stop watch, and chemical tracer dilutions were used to determine the flows into and/or out of the various slaughtering processes and production areas. Figure 2 shows the drainage system from the kill floor. The sampling locations were chosen so far as possible to isolate areas which were expected to have different characteristics. Several different methods were also needed to collect representative samples because the sampling point each had different physical characteristics. In some of the sewers, the flow was intermittent or periodic. In most of the sewers there was no way to continuously monitor flow rate so as to properly make a flow proportioned composite sample. Because of this, a great reliance was placed on tracking the pattern of water use over time and making arithmetic composite based on numerous grab samples which were collected. Table 1 shows the sampling method and the flow measurement method used at each of the sampling locations during the production shift. Similar but more complicated problems were encountered during the clean-up shift when there is a great deal of intermittent operation of valves and hoses. An example of how this was handled is given later.

Samples were collected from all the sampling locations on several different days and collected in order to characterize both the production and the clean-up shift. Laboratory measurements included BOD, COD, organic carbon, grease, several forms of solids, and total Kjeldahl nitrogen. The procedures used were those specified in the EPA laboratory manual.

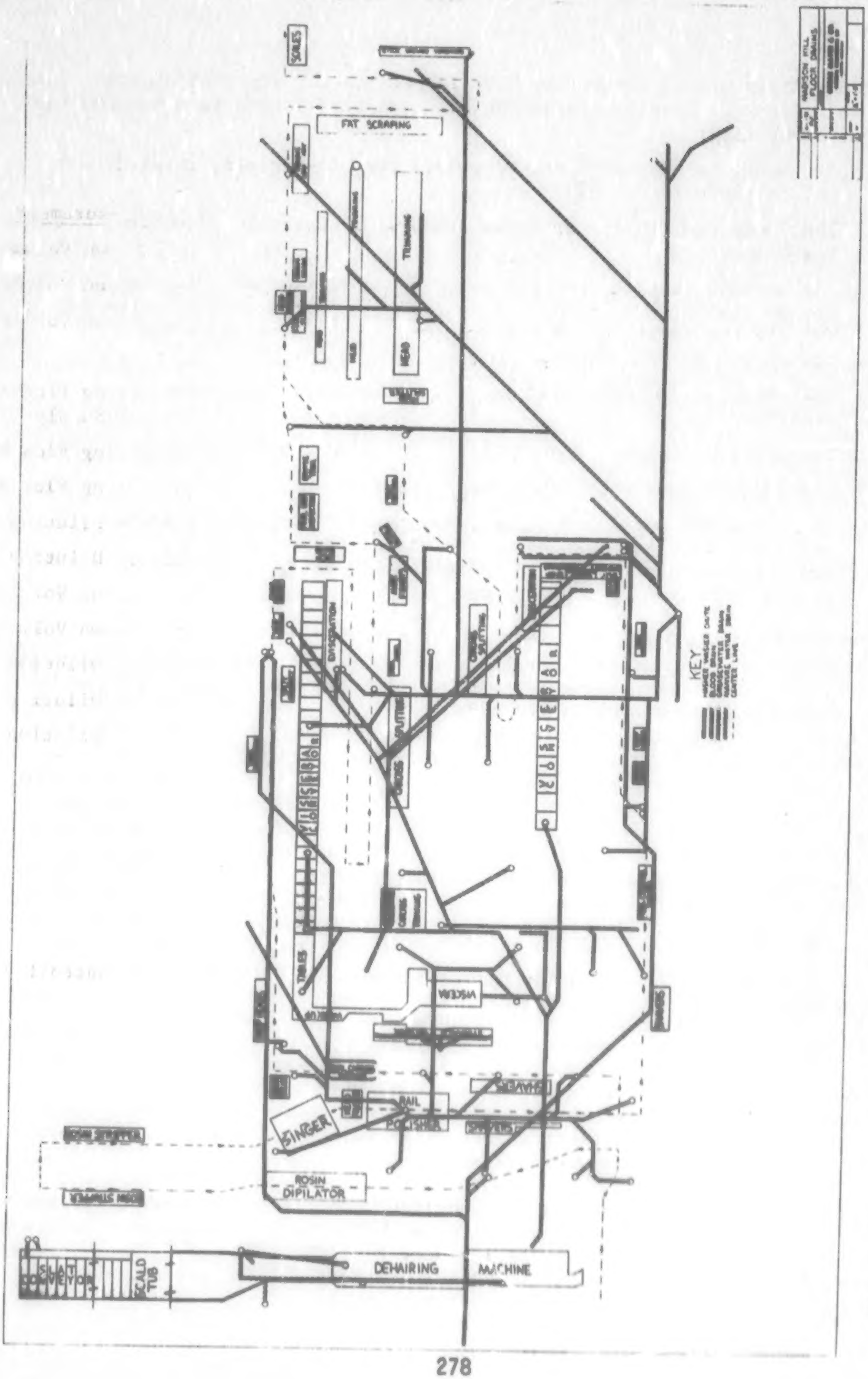
SCALES
FAT SCRAPING
TRIMMING
HEAD
SPLITTING
EVISCERATION
VISCERA
TABLES
SINGER
RAIL
POLISHER
SHAVERS
ROSIN DIPILATOR
ROSIN STRIPPER
SLAT CONVEYOR
SCALD TUB
DEHAIRING MACHINE
KEY
MADISON KILL FLOOR DRAINS

Figure 2. Madison Kill Floor Layout and Drainage Plan.

Table 1. SAMPLING AND FLOW MEASUREMENT METHODS

Sampling Location	Sampling Method	Flow Measurement
1. Bleed Floor Drain	Manual Short-Term Composite	Time Known Volume
2. Bleed Area Floor Drain	Manual Short-Term Composite	Time Known Volume
3. Bleed Conveyor Wash	Automated Grab[a]	Time Known Volume
4. Scald Tank	Manual Short-Term Composite[b]	No Flow[d]
5. Dehair Floor Drain	Automated Grab[c]	Totalizing Flow Meters in Water Supply Lines
6. Rail Polisher	Automated Grab	Totalizing Flow Meter
7. Carcass Shower	Automated Grab	Totalizing Flow Meter
8. Hasher-Washer Drain	Manual Short-Term Composite	Lithium Dilution
9a. Stomach Washer	Manual Short-Term Composite	Lithium Dilution
9b. Neck Washer	Manual Short-Term Composite	Time Known Volume
9c. Head Washer	Manual Short-Term Composite	Time Known Volume
10. "660" Grease Drain	Automated Grab	Lithium Dilution
11. Center Grease Drain	Automated Grab	Lithium Dilution
12. "330" Grease Drain	Automated Grab	Lithium Dilution

---

[a] Isco Automated Sampler.

[b] Five to six grabs composited over 5 to 10 minutes.

[c] One-inch diameter rubber bladder valve with compressed air supply controlled by a solenoid.

[d] Samples were from the scald tank which is dumped during clean-up.

An enormous number of samples had to be collected, processed through the laboratory, and the data from all these analyses had to be converted to information. A system of checks and cross checks on the inventory of samples was designed so that the project manager, the data key punch operators, and the laboratory technicians could all see clearly what schedule was intended and how the data production was progressing in accordance with that schedule. This data management scheme is discussed in the final report of the project.

Table 2 shows the initial characterization of the production shift for the Madison plant with flow and quantities of all pollutants given in terms of thousand pounds of live weight killed. The summarizing tables were prepared from tables for individual pollutants and for flow similar to Table 3. A typical shift was defined from long term production records. The pounds per shift and flow per shift are important numbers for the individual slaughtering plant. In this paper we will express results more commonly in terms of mass per thousand mass units live weight killed because this, hopefully, extrapolates more reasonably to other slaughtering operations.

WASTEWATER CHARACTERIZATION

Table 2 and Table 3 are based on the reduction of a great number of samples. Having great mass of raw data summarized in this form enables one to identify quickly those areas in the kill floor which are the greatest contributors of flow and of various pollutants. For example, Table 2 quickly shows that the dehairing operation contributes roughly 1/4 of the flow from the kill floor; the 660 grease drain is a large contributor of flow but is really not a very substantial portion of the pollutant load, the stomach washer uses large amounts of water and has a very heavy pollutant load, and the hasher-washer is the other most important contributor. This kind of intiial characterization quickly draws one's attention to the areas which hold the greatest potential for conservation. For example, a ten percent reduction in the solids in the hasher-washer drain is the equivalent in pollutional load reduction to eliminating the other solids load in any of the grease drains. It shows that, while small reductions may be possible in certain areas such as the rosin stripper or the rail polisher, these reductions cannot be important in terms of the total load. Small changes should be made whenever possible if the cost and effort is not too great. Clearly, a major investment of time and money to reduce the contribution from the hasher-washer will bring substantial reward.

The same kind of characterization and interpretation was done for the clean-up shift. Because the flow rates during clean-up are so highly variable, the pattern in time was determined by a continuous tracer dilution technique and flow profile such as shown in Figure 3 were developed for each sampling point. At the same time grab samples were collected on which measurements of pollutant concentration were made. Figure 4 shows the profile of BOD during the clean-up shift which corresponds to the flow in Figure 3. This flow and concentration data are used then, to estimate the mass of BOD which was discharged past that particular sampling point during the clean-up shift. At every sample point there was always an initial peak in concentration just as clean-up began. In the examples shown, we see the concentration of BOD dropping from initial values of one to two thousand to concentrations of one to two hundred within the first hour. At some sampling points the concentration dropped even more drastically than this because the area being cleaned was rather well defined

Table 2. INITIAL WASTEWATER FLOW AND POLLUTANT LOAD CHARACTERIZATION OF THE PRODUCTION SHIFT. EXPRESSED PER THOUSAND POUNDS OF LIVE WEIGHT KILL.

Sample point	Flow	Total solids	Total volatile solids	Suspended solids	Total suspended solids	Grease	Total Kjeldahl nitrogen	BOD	COD
Bleed area floor drain	-	-	-	-	-	-	-	-	-
Bleed conveyor blood drain	-	-	-	-	-	-	-	-	-
Bleed conveyor wash drain	1.9	0.036	0.030	0.004	0.003	0.002	0.004	0.014	0.036
Dehair floor drain + scald tank	70.3	1.225	0.875	0.649	0.580	0.180	0.131	.536	1.308
Rosin stripper	8.6	0.054	0.028	0.005	0.004	0	0.002	0.009	0.023
Rail polisher drain	8.9	0.069	0.040	0.009	0.008	0.005	0.005	0.020	0.045
"660" grease drain	21.9	0.136	0.070	0.021	0.018	0.012	0.019	0.037	0.080
Carcass shower(1)	(20.1)	(0.092)	(0.039)	(0.004)	(0.004)	-	(0.008)	(0.010)	(0.030)
Center grease drain	14.3	0.088	0.077	0.033	0.029	0.008	0.045	0.025	0.337
"330" grease drain	16.4	0.430	0.175	0.086	0.080	0.074	0.056	0.169	0.308
Head washer(2)	(4.5)	-	-	-	-	-	-	-	-
Stomach washer drain	48.5	0.981	0.817	0.671	0.605	1.454	0.041	0.537	1.300
Hasher washer drain	53.2	4.340	3.730	2.346	1.880	3.590	0.230	2.700	6.800
Neck washer(3)	(8.6)	(1.020)	(0.980)	(0.472)	(0.440)	(1.580)	(0.020)	(0.360)	(0.900)
Total gallons/1000 lbs LWK[a]	244.0								
Total pounds/1000 lbs LWK[a]		7.36	5.84	3.828	3.208	5.325	0.533	4.047	10.237

[a] Live weight kill

(1) Carcass shower is included in 660 grease drain totals.

(2) Head washer is included in 330 grease drain totals.

(3) Neck washer is included in hasher-washer drain totals.

Table 3. COD SUMMARY OF THE INITIAL CHARACTERIZATION OF THE PRODUCTION SHIFT

Sample point	mg/l	Pounds/ shift	Kilograms/ shift	Pounds 1000 lbs LWK[a]	Percent of load
Bleed area floor drain	-	-	-	-	-
Bleed conveyor blood drain	-	-	-	-	-
Bleed conveyor wash drain	2360	52.5	23.8	0.036	0.4
Dehair floor drain	2230	1882.	854.	1.308	12.8
Scale tank					
Rosin stripper	320	34.0	15.3	0.023	0.2
Rail polisher drain	610	64.9	29.4	0.045	0.4
"660" grease drain	440	114.5	51.9	0.080	0.8
Carcass shower(1)	(200)	(48.2)	(21.8)	(0.03)	(0.3)
Center grease drain	2830	485.0	219.8	0.337	3.3
"330" grease drain	2260	444.3	201.5	0.308	3.0
Head washer (2)	-	-	-	-	-
Stomach washer	3220	1871.0	849.	1.300	12.7
Hasher washer drain	15340	9780.	4436.	6.800	66.4
Neck washer(3)	(13580)	(1402.)	(635.)	(0.90)	(9.5)
Total		14728.2	6680.7	10.237	100.

[a] Live weight kill

(1) Carcass shower is included in 660 grease drain totals.

(2) Head washer is included in 330 grease drain totals.

(3) Neck washer is included in hasher-washer drain totals.

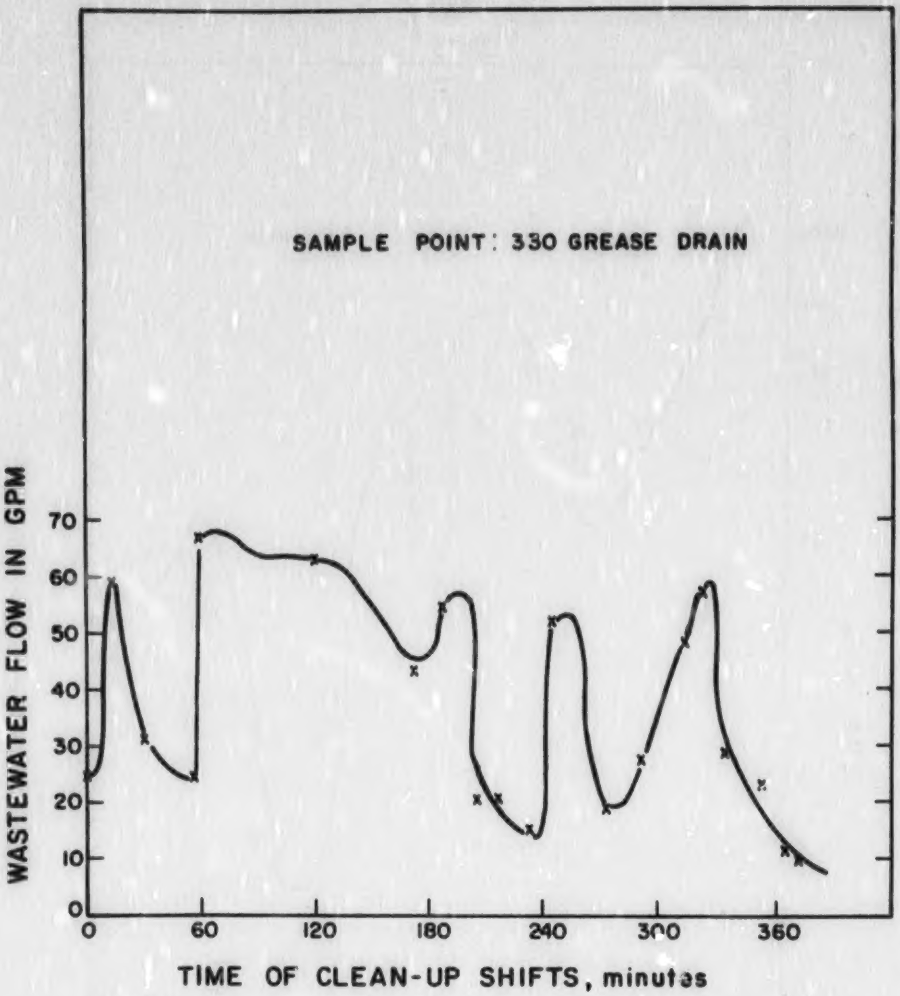

Figure 3. Clean-up Shift Flow Profile

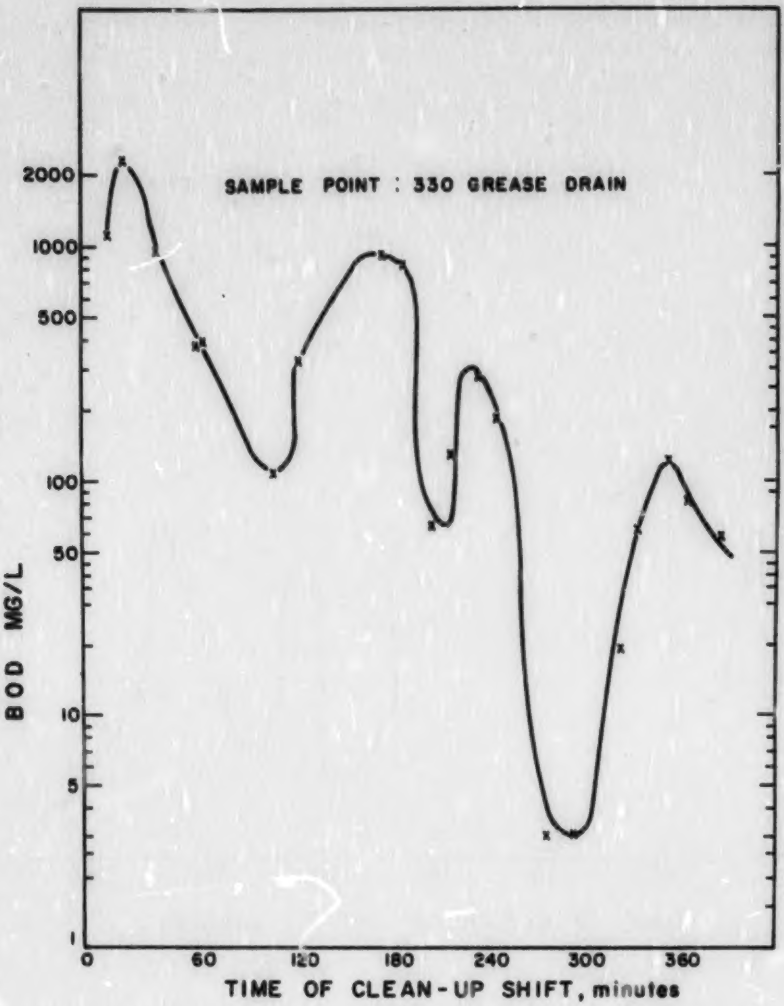

Figure 4. Clean-up Shift BOD Concentration Profile

and the clean-up task was very specific. In the example shown in Figures 3 and 4, the 330 grease drain, the area being cleaned represents several kill processes and as the clean-up crew moves from one piece of machinery to another, additional peaks are seen. Each sampling point had a characteristic clean-up shift profile and these profiles were determined and used to make estimates of the mass and the flow discharge during the clean-up shift which are presented as Table 4.

The total amount of flow and pollutant discharge during a day, the production shift plus the clean-up shift, are given in Table 5 and 6.

A two way comparison of this data is both informative and important. One comparison is the discharge of one process area or one sampling point with another. The second is a comparison of the discharge during the production shift with discharge during the clean-up shift. Figures 5 and 6 graphically make this comparison for flow and BOD for the Madison plant. The totals for the entire hog kill are shown at the right hand edge of these figures.

The water use is divided approximately 1/3 to the clean-up shift and 2/3 to the production shift. The BOD load is much more heavily predominated by the production shift. About 95% of the combined BOD load originates during the production shift and only about 5% is discharged during the clean-up shift.

Similar patterns are found for all of the other pollutants which were measured.

CHANGES

These results indicate that process modifications during the production shift are an important target if water use and pollutant discharges are to be reduced. The general strategies for conserving water during the production shift is to identify wasteful sprays and to reduce or eliminate the use of water for transport of material which could be transported in a dry form. The strategy for reducing pollutant mass during the production shift is generally to be sure that blood cannot enter the sewer and to be sure that meat scraps are picked up and not allowed to be flushed down the drain. Water use during clean-up can often be reduced substantially by insisting that the clean-up personnel do not leave hoses running unattended, to be sure that they do not unnecessarily turn on sprays or forget to turn off process waters. Pollutional loadings can be reduced by being sure that blood and meat scraps are picked up dry.

With the results of the initial characterization for guidance and with these general strategies in mind, a long list of potential process modifications was generated. Many of these changes could not be implemented before the project ended but many worthwhile process changes were actually installed and evaluated in the plant. In some cases the process changes were impossible in the Madison plant, because of physical limitations, space constraints or production constraints. Changes were made in other Oscar Mayer plants and some differences in processes in other plants were used as a basis for estimating the potential value of a change. The kinds of changes installed and evaluated are discussed individually in a later section of the paper. To put these individual changes into perspective, Tables 7 and 8 presented to summarize the reductions which could be accomplished at the Madison plant.

Table 5. INITIAL WASTEWATER FLOW AND POLLUTANT LOAD CHARACTERIZATION OF THE COMBINED PRODUCTION AND CLEAN-UP SHIFTS. EXPRESSED AS PERCENT.

Sample point	Flow	Total solids	Total volatile solids	Suspended solids	Volatile suspended solids	Grease	Total Kjeldahl nitrogen	BOD	COD
Bleed area floor drain	0.5	0.3	0.4	0.2	0.2	0.2	0.7	0.4	0.3
Bleed conveyor blood drain	0.2	0.1	0.2	0.1	0.1	0.02	0.2	0.1	0.1
Bleed conveyor wash drain	0.9	0.5	0.6	0.1	0.1	0.03	0.9	0.4	0.4
Dehair floor drain	37.6	16.2	18.0	21.0	21.1	3.7	26.1	15.5	15.6
Scald tank	(1.5)	-	-	-	-	(0.17)	-	-	-
Rosin stripper	(2.4)	0.5	0.4	0.1	0.1	-	0.4	0.2	0.2
Rail polisher drain	(2.5)	0.7	0.6	0.2	0.2	0.1	0.8	0.5	0.4
"660" grease drain(1)	(8.4)	2.4	1.6	1.0	0.8	0.4	3.7	1.2	1.2
Carcass shower	-	-	-	(0.1)	-	-	-	-	-
Center grease drain	(3.9)	0.8	1.2	0.8	0.9	0.1	8.0	0.6	3.1
"330" grease drain	(7.7)	27.4	4.2	4.7	3.8	2.2	10.1	5.0	3.5
Head washer (2)	-	-	-	-	-	-	-	-	-
Stomach washer drain	14.4	9.4	13.1	15.9	17.7	27.0	7.3	12.7	12.1
Hasher washer drain	21.4	41.7	59.7	55.9	54.8	66.3	41.8	63.4	63.1
Neck washer (3)	-	-	-	(0.1)	-	-	-	-	-
Total %	100	100	100	100	100	100	100	100	100
Gal/shift	521480								
Liters/shift	1973318								
Gal/1000 lb LWK[a]	362.7								
Liters/1000 kg LWK[a]	3025.7								
Lb/shift		15345	9084	6125.7	4956	7802	808	6133.6	15548.7
Kg/shift		6962.3	4117.9	2778.3	2247.9	3537.8	366.7	2782.5	7052.3
Lb/1000 lb LWK[a]		10.674	6.314	4.259	3.451	5.427	0.559	4.266	10.833
Kg/1000 kg LWK[a]		10.674	6.314	4.259	3.451	5.427	0.559	4.266	10.833

[a] Live weight kill

(1) Carcass shower is included in 660 grease drain totals.

(2) Head washer is included in 330 grease drain totals.

(3) Neck washer is included in hasher-washer drain totals.

Table 6. INITIAL WASTEWATER FLOW AND POLLUTANT LOAD CHARACTERIZATION OF THE COMBINED PRODUCTION AND CLEAN-UP SHIFTS. EXPRESSED PER THOUSAND POUNDS OF LIVE WEIGHT KILL.

Sample point	Flow	Total solids	Total volatile solids	Suspended solids	Volatile suspended solids	Grease	Total Kjeldahl nitrogen	BOD	COD
Bleed area floor drain	1.9	.031	.023	.009	.008	.009	.004	.016	.027
Bleed conveyor blood drain	.8	.015	.011	.004	.003	.001	.001	.005	.013
Bleed conveyor wash drain	3.4	.055	.038	.006	.004	.003	.005	.015	.042
Dehair floor drain	136.3	1.729	1.135	.896	.728	.202	.147	.661	1.685
Scald tank	-	-	-	-	-	-	-	-	-
Rosin stripper	8.6	.054	.028	.005	.004	-	.002	.009	.023
Rail polisher drain	8.9	.069	.040	.009	.008	.005	.005	.020	.045
"660" grease drain	30.6	.260	.102	.040	.029	.022	.021	.051	.125
Carcass shower (1)	(20.1)	(.092)	(.039)	(.004)	(.004)	(-)	(.008)	(.010)	(.030)
Center grease drain	14.3	.088	.077	.033	.029	.008	.045	.025	.377
"330" grease drain	27.8	2.928	.264	.201	.132	.120	.057	.215	.360
Head washer (2)	-	-	-	-	-	-	-	-	-
Stomach washer drain	52.1	1.000	.828	.677	.612	1.461	.041	.542	1.315
Hasher washer drain	78.0	4.445	3.768	2.379	1.894	3.596	.231	2.707	6.821
Neck washer (3)	-	-	-	-	-	-	-	-	-
Total gallons/1000 lb LWK[a]	362.7								
Total lbs/1000 lb LWK[a]		10.674	6.314	4.259	3.451	5.427	.559	4.266	10.833

[a] Live weight kill

(1) Carcass shower is included in 660 grease drain totals.

(2) Head washer is included in 330 grease drain totals.

(3) Neck washer is included in hasher-washer drain totals.

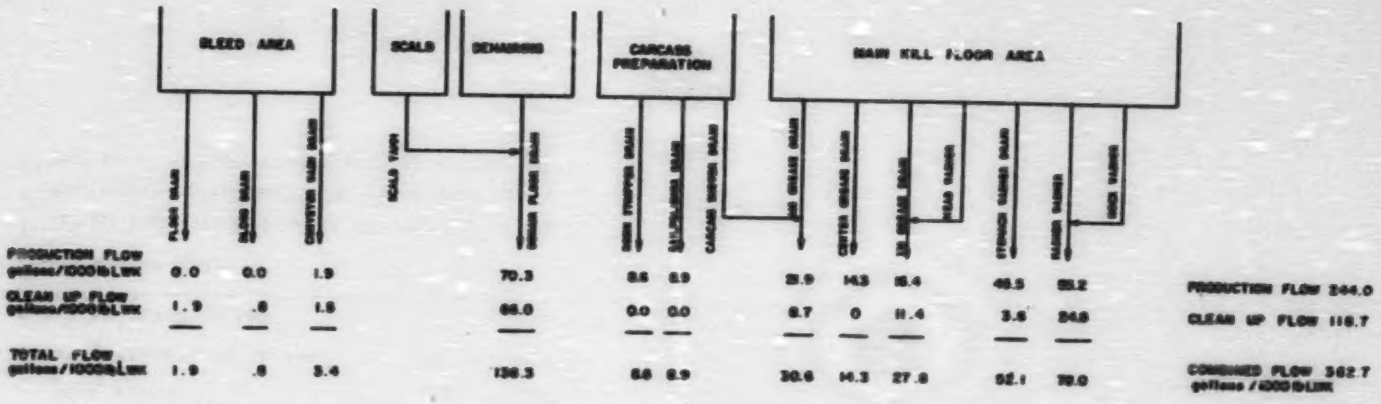
BLEED AREA
SCALD
DEHAIRING
CARCASS PREPARATION
MAIN KILL FLOOR AREA
FLOOR DRAIN
BLOOD DRAIN
CONVEYOR HAIR DRAIN
SCALD TANK
CARCASS SHOWER DRAIN
CENTER GREASE DRAIN
HEAD WASHER
PRODUCTION FLOW gallons/1000lbLWK
0.0
0.0
1.9
70.3
8.6
8.9
21.9
14.3
16.4
48.5
55.2
CLEAN UP FLOW gallons/1000lbLWK
1.9
.8
1.5
66.0
0.0
0.0
8.7
0
11.4
3.6
24.8
TOTAL FLOW gallons/1000lbLWK
1.9
.8
3.4
136.3
8.6
8.9
30.6
14.3
27.8
52.1
80.0
PRODUCTION FLOW 244.0
CLEAN UP FLOW 118.7
COMBINED FLOW 362.7 gallons/1000lbLWK

Figure 5. Wastewater Flow Mass Balance for the Madison Production and Clean-up Shifts.

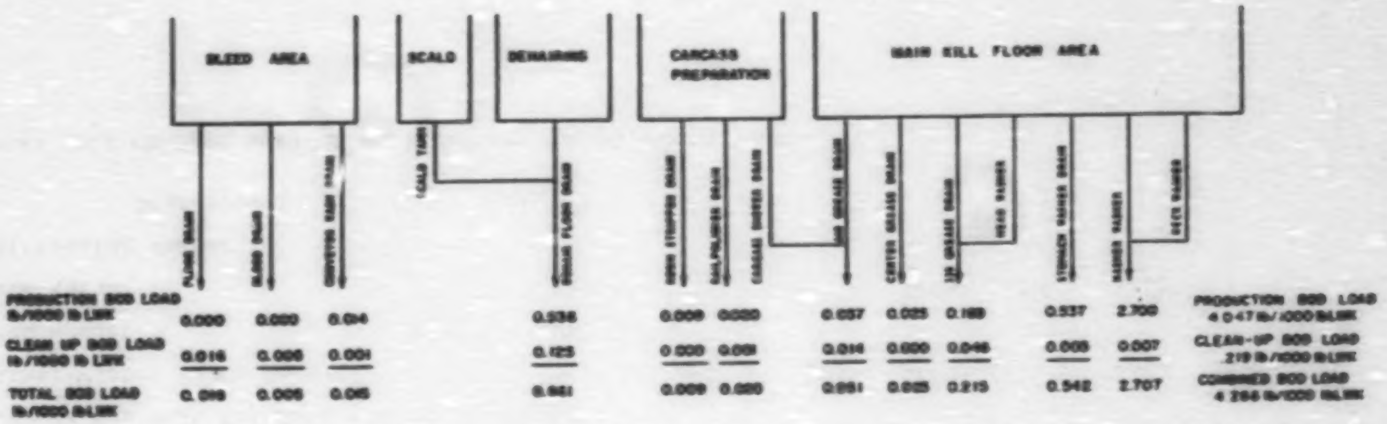
BLEED AREA
SCALD
DEHAIRING
CARCASS PREPARATION
MAIN KILL FLOOR AREA
FLOOR DRAIN
BLOOD DRAIN
CONVEYOR WASH DRAIN
SCALD TANK
DEHAIR FLOOR DRAIN
HORN STRIPPER DRAIN
TAILPULLER DRAIN
CARCASS SHOWER DRAIN
LH GREASE DRAIN
CENTER GREASE DRAIN
RH GREASE DRAIN
HEAD WASHER
STOMACH WASHER DRAIN
HASHER WASHER
GUTS WASHER
PRODUCTION BOD LOAD lb/1000 lb LWK
CLEAN UP BOD LOAD lb/1000 lb LWK
TOTAL BOD LOAD lb/1000 lb LWK
0.000 0.000 0.014 0.536 0.009 0.000 0.037 0.025 0.169 0.537 2.700
0.016 0.006 0.001 0.125 0.000 0.001 0.014 0.000 0.046 0.005 0.007
0.016 0.006 0.015 0.661 0.009 0.020 0.051 0.025 0.215 0.542 2.707
PRODUCTION BOD LOAD 4.047 lb/1000 lb LWK
CLEAN-UP BOD LOAD .219 lb/1000 lb LWK
COMBINED BOD LOAD 4.266 lb/1000 lb LWK

Figure 6. BOD Mass Balance for the Madison Plant Production and Clean-up Shifts.

Table 7. FLOW AND/OR POLLUTION REDUCTION DUE TO CHANGES EXPRESSED IN GALLONS AND POUNDS

Problem Area	Water	BOD_5	COD	TS	TSS	Grease	TKN	Solids
Bleed Trough		5 Lbs.						
Bleed Trough Clean-Up		5 Lbs.						
Bleed Conveyor Sprays	2,670							
Hair Chute - Davenport	110,000	506	1302	1366	704	149	107	
Rail Polisher Shut-Off								
Beardstown	2,400							
Final Carcass Shower								
Madison	8,753							
Beardstown	21,330							
Eyelids on Floor								12 Lbs.
Brisket Splitting Carcass Splitting - Vacuum Clean-Up		170	903	790	148	60	103	
Viscera Pan Wash Sprays	39,427							
Viscera Pan Wash Solenoid Valves	29,825							
Hasher-Washer Blade Removal		2948	7505	4180	2906	3275	138	
Head Washer	3,260							
Neck Washer	3,034	257		1005	381	1705		
Chitterling Washer								
Beardstown	51,850							

Note: All changes were made in Madison except where noted.

Table 8. COST OF CHANGES AND SAVINGS RESULTING FROM CHANGES

Problem Area	Cost of Change	Annual Savings
Bleed Trough	$ 0.00	$ 40
Bleed Trough Clean-Up	$ 3.00	$ 40
Bleed Conveyor Sprays	$ 0.00	$ 260
Hair Chute - Davenport	$22,000	$19,406
Rail Polisher Shut Off - Beardstown	$ 255	$ 624
Final Carcass Shower - Madison	$ 184	$ 853
Beardstown	$ 86	$ 2,080
Eyelids on Floor	$ 86	-------
Brisket Splitting Bone Dust - Carcass Splitting Viscera Pan Wash Sprays	$ 2,377	$ 4,078
Viscera Pan Wash Solenoid Valves	$ 1,285	$ 2,907
Hasher-Washer Blade Removal	$ 275	$42,697 Pollution Reduction $96,244 Increased Byproduct Recovery
Head Washer	$ 0.00	$ 831
Neck Washer	$17,000	$30,000 Reduced Labor $ 4,858 Reduced Pollution & Water Consumption
Chitterling Washer - Beardstown	$ 78	$ 5,070

Note: All changes were made in Madison except where noted.

It is estimated that changes actually installed plus the use of processes which exist in other Oscar Mayer plants would yield a 41% reduction in flow. This is slightly more than 200,000 gallons per day, and at 60% reduction in BOD and suspended solids, this represents nearly 4,000 pounds of BOD and 4,000 pounds of suspended solids per day. Similar reduction would be accomplished for nitrogen, grease, and the other pollutants measured. However, other factors such as physical layout, cost and product quality considerations preclude complete adoption at Madison and other older plants.

The savings in water used and wastewater discharged to treatment can be translated into very large monetary savings. The cost savings show in Table 8 has been estimated using the value of $0.15 per thousand gallons for cold potable water input to the process, as sewer service charge with a volume component of $0.24 per thousand gallons, plus a BOD component of $0.0319 per pound and a suspended solids component of $0.0264 per pound. The work year was taken as 250 working days. These unit costs represent the water and wastewater charges at the Madison plant. The wastewater charges are similar to those paid to the City of Madison for accepting pretreated industrial wastewater. It has not been possible to estimate the actual impact of these changes on the Oscar Mayer pretreatment plant, nor has it been possible to estimate the changes in operating cost of that pretreatment plant due to the reduced waste loads. It is felt that these charges give a reasonable basis for discussion and provides a realistic method of computing savings.

PROCESS CHANGES

Problem: Blood clots build up in the bleeding trough. If the collected mass becomes heavy enough, it breaks free and drains into the blood recovery tank too fast for the system to handle it. Some of this blood spills onto the floor and gets into the greasewater sewer system. The amount of blood lost this way was not large, only about 25 pounds/day but this is 5 pounds BOD_5.

Solution: The sticker now places the front leg of every 30th or 40th hog so that it drags along the trough. This breaks the clots free before they grow to an unmanageable size.

Problem: After the last hog of the day was stuck, the clean-up man would use water sprays to sluice most of the blood left in the trough to the blood recovery system.

Solution: A rubber squeegee, made to fit the bleeding trough, is now used to dry clean the bleeding trough and recover the blood. After squeegeeing the trough the drains are changed so that water goes to the greasewater drainage system. Dry cleaning has reduced the blood loss by approximately 25 pounds/day and the additional blood recovered is easier to process because it is drier.

Problem: Cold water, 26,670 gallons per average production shift, sprayed continuously onto the slotted end of the bleeding conveyor to wash off blood.

Solution: The sprays were eliminated during production, they are used during clean-up. The continuous washing did not remove all of the blood so clean-up was always needed anyway. Eliminating the sprays did not clean-up more difficult.

Problem: Hog hair and toenails removed in the dehairing machine are dropped into the plant manure water drainage system and flushed to the sewage treatment plant where the solids are removed on a shaker screen. Because of the bulk of the hair and the fact that it sometimes becomes matted, 110,000 gallons/day of potable water are used to flush the hair through the system.

Solution: No changes have been made at the Madison plant, however, the two methods of handling the hair used in the Davenport and Beardstown plants are being investigated. In Davenport, hair discharges from the dehairing machine by a chute into a truck body located three floors below. This completely eliminates the need for transport water. In Beardstown, recycled water from the grease flotation tank is used to transport the hair to the sewage treatment plant. This eliminates the need for potable water for transporting hair.

Problem: Clean-up personnel leave the rail polisher sprays on during clean-up. The water serves no useful purpose in clean-up and 1,640 gallons of water/hour are wasted.

Solution: In Beardstown, an automatic switch turns off the water after the last hog has passed through the polisher. The switch consists of a 36 inch push bar which is moved by the hog trolley moving along the kill rail, to activate a micro-switch which controls a solenoid valve on the water supply line. An emergency bypass valve for use in case of malfunction of the solenoid valve is located out of convenient reach of the clean-up man.

Problem: The final carcass shower uses too much water. Consumption measured at start of study was 60 GPM.

Solution: Different sets of sprays were tried in Madison and in Beardstown. In Madison, four nozzles were installed to spray across the hams and allow the water to run down the sides of the carcass to sluice off loose material. Also, a line of six Veejet sprays were placed along one side of the shower cabinet to scour off small rosin flakes which are imbedded in the back. These sprays reduced the water used from 60 GPM to 46 GPM. Further work is needed on these sprays since they produce a fine mist which drifts onto people working nearby. In Beardstown, two nozzles spray the hams and two whirljet nozzles (one on each side of the cabinet) spray the sides of the carcass. This spray system uses 15 GPM of water.

Problem: Eyelids and scraps of skin trimmed from the carcasses are dropped onto the floor. Despite periodic dry pick-up, much of the material was washed down the drain. Because of labor standards for the job, it was not possible to have the trimmers put the scraps into a barrel.

Solution: A combination screen and bridge of stainless steel was built across the drain to keep the scrap out of the drain so that it could be picked up for disposal in inedible rendering.

Problem: When the brisket is split, large quantities of blood serum and blood clots drop out of the chest cavity onto the floor. A nearby blood drain carries the blood serum to the blood recovery system. The blood clots get swept to the hasher-washer drain during periodic mid-shift clean-ups. In the hasher-washer, the clots break up and flow out with the wastewater.

Solution: An industrial wet/dry vacuum cleaner was purchased to use during mid-shift and daily clean-up to get blood and meat scraps off the floor. The vacuum cleaner picked up everything and left the floor clean and dry. Unfortunately, the machine was too cumbersome, required too much time, and interferred with production. One solution is to eliminate the use of the hasher-washer drain as a handy disposal for all kill floor wastes. Bloody material must be picked up for disposal directly into inedible rendering by broom (or squeegee) and shovel, or by vacuum cleaner.

Problem: Sawdust from the carcass splitting saws is carried down the drains, by the cooling water used with the saws or it is swept down the drains during mid-shift and daily clean-up.

Solution: At Madison, dry clean-up (broom and shovel) is used. The material is placed in a barrel for inedible rendering. In Davenport, a stainless steel catch pan was designed which slopes to a chute leading to inedible rendering. All of the sawdust can then be swept directly to inedible rendering.

Problem: Wastewater from drinking fountains, lavatories and overspray from the treadmill washer flow across blood clots in the gutter near the eviscerating treadmill and leach out soluble pollutants.

Solution: Water was diverted from the gutter and the blood on the floor was kept as dry as possible until it could be picked up during periodic clean-up. Another solution would be to build a stainless steel trough under the kill chain to catch all blood clots and any tissue trimmed from the carcasses. This solution was not tried since the kill chain in Madison is too low. The heads of the largest carcasses would touch any trough elevated more than three inches off the floor; a trough this low would interfere too much with clean-up.

Problem: The viscera pan washer and the eviscerating treadmill water use excessive amounts of water. Continuous sprays on both of these conveyors wash them according to USDA Regulation. Some of the sprays were 1/8 inch holes drilled in a 1 1/2 inch pipe. Many of the nozzles used on the treadmill washer were oversized.

Solution: Spraying Systems Co. helped design sprays which would do the job using the least amount of water. Water use was reduced from 115 gallons/min. to 40 gallons/min.

Problem: Clean-up workers would leave water running in the viscera pan and treadmill washers for several hours during clean-up.

Solution: Solenoid valves controlled by an electrical timer were installed on all of the water lines to the viscera pan and treadmill washers. During production, water is needed continuously and the timer is set on manual so the solenoid valves remain open. At the end of production, the timer is set on automatic and the cabinet is locked. The clean-up man can use the sprays by pushing a switch on the outside of the cabinet which turns on the sprays for 15 minutes only. This switch can be activated as often as needed. Clean-up personnel cannot leave the water running for hours just because they forgot to turn it off.

Problem: The hasher-washer is the largest contributor of pollutional material from the kill floor. The hasher-washer recieves the condemned viscera, all intestines, pizzle and piggy bags and the fat and tissue from the neck washer. When the intestines are slashed open, their contents are washed out to the drain. The large size of the openings in the washer screen also allows the small particles of fat and other connective tissue from the neck washer to pass through and be lost to the drain.

Solution: The blades were removed from the hasher-washer so that the intestines went to inedible rendering intact. This increased the daily yield of meat scraps by 8,500 pounds/day while reducing the BOD loading from the kill floor by over 50%. There was some lowering in grease quality when this was done, but this loss was overshadowed by the increased quantity of meat scraps. A further test, which was not tried, is to replace the present screen with a fine mesh dewatering device which will retain small particles of fat and tissue.

Problem: The stomach washing process consists of a slitter - dumper where the stomachs are slit open and the contents are flushed out and a tumble washer which uses a continuous flow of water to wash the contents from the stomachs before the mucosa is stripped. It was felt that too much water was used and discharge has a high pollutional loading.

Solution: A fully satisfactory solution was not found. Less water in either the slitter - dumper or the tumble washer fails to remove all of the contents from the stomachs and made the muscosa unacceptable for pharmaceutical use. Tests indicate the average weight of a stomach's contents is one pound, of which 81% is water. Of the 19% that is solids, 1.83% is protein. Many of these solids are soluble and once dissolved, are not recoverable by screening. The portion of the stomach contents that filtered through a 20 mesh screen analyzed at 41,000 ppm TS, 37,000 TVS and a BOD_5 of 42,000 ppm. What is needed is a slitter - dumper which will dump the stomachs dry and convey the materials to some place for landfill disposal or for drying and refeeding.

Problem: Six shower spray nozzles were used to wash the carcass cavity and heads before the heads were removed from the carcass for processing.

Solution: The number of shower nozzles were reduced to three and the pressure was reduced from 60 psi to 20 psi saving 18 GPM.

Problem: The manually operated neck washer used too much water and scraped off too much fatty tissue which was lost to the drain.

Solution: In Beardstown and Davenport tanks were placed under the kill rail in the neck washing area. The tanks are equipped with surface weirs which discharge the water while retaining floating fatty solids. The solids are removed at the end of the shift and sent to inedible rendering.

Tests were run using a vacuum system to remove the blood clots from the stick wound. However, the clots were too firmly imbedded in the connective tissue and could not be removed using just the vacuum.

A Chad Neck Washer was installed in Madison. This machine uses an oscillating set of sprays at 800 psi to scour blood from the stick wound. The Chad Unit does not remove as much fat and connective tissue as the manual washers and it uses less water than two manual washers---20 GPM vs. 26 GPM. Because of the wide spray pattern, the unit also does a good job of washing the interior of the carcass. By relocating the neck washer, it is hoped it can be used to wash the heads and interior of the carcasses and eliminate the use of the separate head washer.

Problem: Beardstown is the only Oscar Mayer plant where chitterlings are still saved. The chitterling washers use too much water. Most of the water was being used through eight shower nozzles to wash workers hands and the exterior of the chitterlings.

Solution: The shower nozzles were replaced with Spraying Systems Co. 3/8 inch GG "Fulljet" Nozzles. Meter readings show a reduction in water use of 51,850 gallons/day for three chitterling machines.

CONCLUSIONS

There is no argument that there is a need in the meat packing industry to conserve water and reduce pollutional loadings in wastewater. Quantification by metering and analysis is usually not necessary unless information is desired concerning the savings generated by making a change. Most of the processes which are heavy polluters or large users of water are readily identifiable by visual observation and by having a thorough knowledge of slaughtering processes. Each place in the slaughtering process where water is used must be examined to determine if the water is really necessary, or if it is being used in the most efficient manner.

Whether or not water can be reused within the plant will depend greatly upon the processes the water is to be used in and whether the local USDA inspector will approve of the use. At Oscar Mayer, reuse water is used in one plant to sluice hair to the sewage treatment plant, and in another plant to sluice condemned viscera to the hasher washer. We are questioning reuse water for these purposes, however, since the water leaches pollutional material from the wastes being transported. It is felt that dry conveying would be better.

It is important that any changes which are made to reduce water use or pollutional loading be done without increasing human labor. At the present time, it is less expensive to pay the extra surcharge cost for over a ton of BOD rather than add one man day of labor to a process.

POULTRY PROCESSING WASTEWATER-
ADVANCED TREATMENT AND REUSE**

by

Daniel T. McGrail*

INTRODUCTION

A water reuse project is currently under investigation by the Bureau of Sanitary Engineering of the Maryland State Department of Health and Mental Hygiene. An advanced treatment plant was designed and built to study the possibility of recycling poultry processing wastewater. The final report was published in March 1974. It demonstrated that the reclaimed water satisfies the chemical, biological, and physical limits for potable grade water. It was recommended, however, to continue the study in order to demonstrate the presence of any health significant characteristics not demonstrated by existing drinking water standards. Also, this study is to show the safety of poultry processed in this reclaimed water.

The funds were renewed and data collection will continue through August 1976 when the final report and recommendations will be published. Much of the data already compiled, however, can be used to investigate the feasibility of constructing a similar plant to meet the E.P.A. proposed poultry processing wastewater discharge limitations. As the deadlines for the proposed 1977 and 1983 effluent standards approach (see table 1) most meat packing and poultry processing plants will require treatment past the existing secondary treatment. The aerated lagoons, followed by the advanced water treatment, consisting of microstraining, flocculation and sedimentation, and sand filtration is a system certainly worth looking into.

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* Maryland State Department of Health and Mental Hygiene, Bureau of Sanitary Engineering.

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TABLE 1. PROPOSED POULTRY PROCESSING PRODUCTS LIMITATIONS 4/24/75 RED. REG. VOL. 40, NO. 8

Subcategory		7/1/77 Best Practicable Technology			New Sources	7/1/83 Best Available Technology			
		BOD_5	TSS	O&G	$BPT+NH_3-N$	BOD_5	TSS	O&G	NH_3-N (mg/1)
Chicken Processors:*	Max:**	0.92	1.24	0.40	0.40	0.60	0.68	0.40	8
	Ave:***	0.46	0.62	0.20	0.20	0.30	0.34	0.20	4
Turkey Processors:	Max:	0.78	1.14	0.28	0.28	0.42	0.48	0.28	8
	Ave:	0.36	0.57	0.14	0.14	0.21	0.24	0.14	4
Fowl Processors:	Max:	1.22	1.44	0.30	0.30	0.46	0.54	0.30	8
	Ave:	0.61	0.72	0.15	0.15	0.23	0.27	0.15	4
Duck Processors:	Max:	1.54	1.80	0.52	0.26	0.78	0.92	0.52	8
	Ave:	0.77	0.90	0.26	0.13	0.39	0.46	0.26	4

Fecal coliform limit is 400mpn/100ml
1983: TKN=4mg/1, TP=2mg/1, NO_3/NO_2-N=5mg/1

*All units are kilograms/1000 kilograms live weight killed unless listed milligrams/liter.
** Maximum for any one day
***Average of daily values for thirty consecutive days.

BACKGROUND

The site of this project is the Sterling Processing Corporation in Oakland, Md. It is presently engaged in the slaughtering, eviscerating, and processing of broilers. The present plant capacity is 6000 birds an hour with a daily average of 175,000 pounds live weight killed. The present operational wastewater lagoon system consists of rotary screening, a primary and secondary aerated lagoon system and a chlorine contact chamber.

This project was initiated due to the limited water resources of the area. After strict water conservation measures, usage was cut from 11 gallons per bird to less than 7. The town of Oakland still could not supply Sterling with its needed 300,000 gallons per day. Three deep wells and a water treatment plant consisting of flocculation and sedimentation, sand filtration, and chlorination were constructed. Geological studies have indicated that additional wells will not increase the ground water supply. Periodic water shortages still plague this plant, particularly during the summer months. The advanced water treatment plant facilities were designed to allow the reclaimed water to enter the plant as a raw water source, before the existing water treatment. (Figure 1)

RAW WASTEWATER CHARACTERISTICS

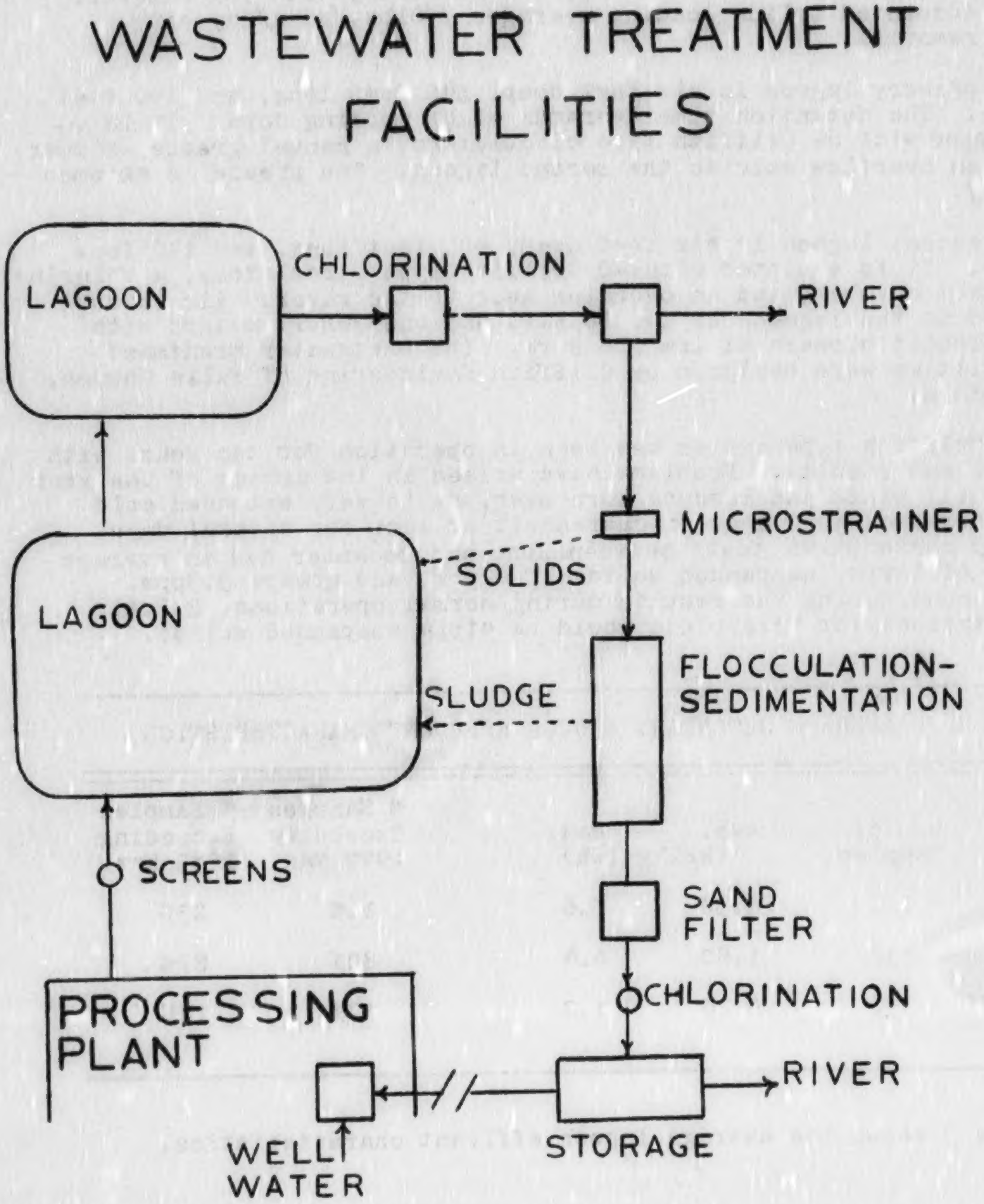
Composite samplers were used to collect daily wastewater samples from the processing plant. Table 2 shows the results of these samples. Average wastewater flow from the plant is 300,000 gallons per day.

TABLE 2. RAW WASTEWATER CHARACTERISTICS

	No. of Samples	Ave.	Max.	Min.	Stan. Dev.
		(k/kkg lwk)*			
BOD_5	148	7.7	14.8	2.0	3.2
TSS	119	11.9	39.5	2.5	6.7
O&G	47	5.7	66.4	1.2	3.4

*300,000 gallons per day and 175,000 lbs. lwk.

Figure 1.


WASTEWATER TREATMENT FACILITIES
LAGOON
CHLORINATION
RIVER
MICROSTRAINER
SOLIDS
LAGOON
FLOCCULATION-SEDIMENTATION
SLUDGE
SCREENS
SAND FILTER
CHLORINATION
PROCESSING PLANT
RIVER
WELL WATER
STORAGE

WASTEWATER LAGOON SYSTEM

The wastewater lagoon system is an effective economical method of treatment. BOD_5 loadings average 450lbs./acre/day with 93% removal, grease is loaded at 330lbs./acre/day with 96% removal, and suspended solids loading averages 750lbs./acre/day with 79% removal.

The primary lagoon is six feet deep, 540 feet long, and 140 feet wide. The detention time averages eight working days. It is equipped with 64 Griffith type circulators, a manual grease skimmer and an overflow weir to the second lagoon. The grease is skimmed daily.

The second lagoon is six feet deep, 400 feet long, and 140 feet wide. It is equipped with 40 Griffith type circulators, a chlorine contact chamber, and an overflow weir to the river. Air is supplied to the lagoons by two 20 H.P. and one 30H.P. motors with Suterbuilt blowers at low pressure. The wastewater treatment facilities were designed by Griffith Engineering of Falls Church, Virginia.

The Griffith type system has been in operation for ten years with excellent results. Problems have arisen in the spring of the year when all ponds and lagoons turn over, on in very extended cold weather such as 0 degrees Fahrenheit or less for several days. Fifty consecutive tests between June and December had an average BOD_5 of 15ppm, suspended solids of 62ppm, and grease 3.3ppm. Even considering the results during normal operations, E.P.A. limitations for this plant would be 41ppm suspended solids.

TABLE 3. AVERAGE SECONDARY LAGOON EFFLUENT CHARACTERISTICS

	No. of Samples	Ave.	Max.	% Samples Exceeding 1977 Max.	% Samples Exceeding 1983 Max.
		(k/kkg lwk)			
BOD_5	121	0.50	5.6	16%	23%
TSS	131	1.80	6.4	80%	87%
GREASE	59	0.20	1.2	12%	12%

Table 3 shows the average lagoon effluent characteristics.

MICROSTRAINER

The microstrainer, part of the original study which did not include facilities for flocculation and sedimentation, was designed to handle an average BOD_5 of 15 ppm, suspended solids of 60 ppm, and grease of 8 ppm. It was found that the discharge from the lagoons exceeded these values during extreme weather conditions. Due to blockage of the screens it was necessary to change the 30 micron screens with a 70 micron screen. These screens are continually backwashed by cold water sprays, and a hot water spray is available when necessary. Replacement of the screens did increase the maximum flow through the unit, however, it cut its treatment efficiency in half. Though the problems have been greatly reduced, when the worst conditions exist, flow through the unit diminishes.

Table 4 shows the treatment efficiency of the microstrainer.

TABLE 4. EFFECTIVENESS OF MICROSTRAINER

	No. of Samples	Ave. (k/kkg	Max. lwk)	% Samples Exceeding 1977 Max.	% Samples Exceeding 1983 Max.
BOD_5	21	0.42	1.7	13%	18%
TSS	18	1.4	3.0	68%	78%
Grease	-	-	-	-	-

FLOCCULATION AND SEDIMENTATION

Following the microstrainer the water begins the flocculation and sedimentation process. These facilities were designed by James D. Clise of the Maryland State Department of Health and Mental Hygiene.

Extensive jar tests were conducted to determine the most effective dosages of alum and lime. The use of a polyelectrolytic coagulant aids was studied. The tests were done using one liter samples of microstrainer effluent. After chemical additions, stirring rates were consistant. The flash mixing rate was 100 rpm, followed by flocculation at 50 rpm for 15 minutes, then finally sedimentation for 30 minutes.

The results of the jar tests showed the best floc formation with dosages of 100 ppm alum, 35 ppm lime and 1 ppm of HERCOFLOC 818.2, a slightly anionic coagulant aid. It is manufactured by Hercules Chemicals of Wilmington, De. These dosages are checked regularly by daily jar tests, but the levels usually remain constant.

It was found that through the introduction of the coagulant aid, suspended solids removal increased from 60% to 70% in the settling basin. The jar tests also gave an indication of the sludge production rate. In a one liter sample after the normal test procedure 100 ml of sludge settles. This rate of sludge build up has caused serious operational problems. Normally every two million gallons treated requires the complete shutdown of the advanced treatment unit while the sedimentation basin is drained and the sludge is pumped. The difficulty in sludge removal is due to an insufficient slope on the bottom of the basin. Though there is a slope the texture and thickness of this sludge is such that it will not flow or drain properly.

Flocculation and sedimentation is a very critical step in the treatment process. Not only is 70% of the suspended solids removed and 80% of the BOD_5 removed but it is very successful for the removal of colloids not removed by either sand or diatomaceous filtration.

One more comment on chemical dosages is worth noting. At present the goal is much higher than a standard waste treatment plant. Of 46 tests only one exceeded 1977 maximum day limits and 2 exceeded 1983 limits for suspended solids. All BOD_5 and grease tests met 1983 limits. Dosages could be greatly reduced if sand filtration was to follow sedimentation. The result, of course, reduced costs.

Table 5 shows the effectiveness of the flocculation and sedimentation process.

TABLE 5. EFFECTIVENESS OF FLOCCULATION AND SEDIMENTATION

	No. of Samples	Ave. (k/kkg lwk)	Max. (k/kkg lwk)	% Samples Exceeding 1977 Max.	% Samples Exceeding 1983 Max.
BOD_5	28	0.09	0.45	0.0%	0.0%
TSS	46	0.46	2.13	2.2%	4.3%
GREASE	24	0.042	0.13	0.0%	0.0%

SAND FILTER

A simple sand and gravel gravity filter follows the flocculation and sedimentation process. This step is necessary to insure proper levels of suspended solids. Potable grade water is the result of this process, the water quality is so high that none of the samples even approach the pollution discharge limits for 1983.

Something to consider, however, is the length of run of the sand filter. Presently filter runs average 200,000 gallons between backwashes, or 16 hours of continuous operation. If the chemical dosages were cut back this figure would almost certainly drop. The backwashing procedure is simple. It only takes approximately five minutes and by using the extra storage capacity in the settling basin a thorough backwash can be completed without a plant shutdown.

The effectiveness of the sand filter is shown in table 6.

TABLE 6. EFFECTIVENESS OF SAND FILTRATION

	No. of Samples	Ave. (k/kkg	Max. lwk)	% Samples Exceeding 1977 Max.	% Samples Exceeding 1983 Max.
BOD_5	56	0.016	0.11	0%	0%
TSS	49	0.074	0.20	0%	0%
GREASE	27	0.035	0.082	0%	0%

DISINFECTION

Chlorination is performed twice throughout the treatment process. After the second lagoon enough chlorine is added to carry a 0.1 ppm free residual through the sand filter. This is accomplished by applying a normal dose of 25 pounds per day or 10 ppm. Final disinfection is then accomplished by another application of 25 pounds per day.

Under no conditions was the fecal coliform limit of 400mpn/100ml exceeded, and since September 1975, when repairs were made in the chlorine injector, all test results have shown an mpn of less than 2. That is the limit of sensitivity for bacteriological tests at the state branch laboratory.

Table 7 shows the effectiveness of disinfection.

TABLE 7. DISINFECTION

	No. of Samples	Ave. MPN/100ml	Max. MPN/100ml
TOTAL COLIFORMS	84	<2	8
FECAL COLIFORMS	84	<2	<2

ECONOMICS

The last consideration, of course, is economics. As of March 1974 the total annual cost of the lagoon system was $22,500 or $.31/1000 gallons. The advanced treatment costs were determined to be $19,500 per year, for a totalcost of $42,000 per year. These costs include interest on the investment, chemicals, power, and one full time operator shared between the two units.

Construction costs of the wastewater lagoon system was $84,000 not including land costs. Construction costs of the advanced treatment unit totalled $90,000 for a combined cost of $174,000.

Considering the plant production is 40 million lbs. lwk per year, it costs approximately 0.1¢ per pound lwk or 0.14¢ per pound dressed weight. These costs alone demonstrate the economical feasibility of a plant of this nature. (Table 8.)

SUMMARY

It has been shown that flocculation and sedimentation followed by sand filtration is an economically feasible method of upgrading an existing aerated lagoon system.

The microstrainer, installed before the flocculation and sedimentation facilities, is the cause of many of the operational problems due to the variations in the lagoon effluent.

The difficulty in sludge removal in the sedimentation basin is a problem that could be overcome in future designs.

The sand filters need for frequent backwashing is a daily maintenance procedure that does not require a plant shutdown.

TABLE 8.

TREATMENT SUMMARY

AVERAGE PER CENT REMOVAL	LAGOONS	STRAINER	FLOCCULATION-SEDIMENTATION	FILTRATION	OVERALL
BOD_5	93	15	78	82	99.8
TSS	79	21	67	84	99.4
GREASE	96	–	–	18	99.4

ALTERNATIVES FOR TREATING POULTRY PROCESSING WASTEWATER

by

Dr. Franklin E. Woodard*

INTRODUCTION

The processing of poultry for the retail trade has been developed as a "water intense" industry. Water is used in large quantities because of its superior heat transfer qualities and for reasons of sanitation. Furthermore, this industry, like most others, was developed during a time when water pollution was considered far less important than low cost production. Public Law 92-500, or the 1972 ammendments to the Clean Water Act of 1969, have placed this nation in a totally different situation. Environmental pollution is now at least as important as production cost; therefore, it seems reasonable that many of the processing methods which were developed under former circumstances should be changed.

Basically, there are two approaches to the problem of decreasing the discharge of water pollutants from a processing plant. One is to build treatment systems, and then more treatment systems to treat the effluent from the first treatment systems, until the desired water quality is finally achieved. The second is to change the methods used in the processing plant so that less water pollutants will be generated. Both approaches require substantial technological development and a period of testing before satisfactory performance can be assured.

In administering Public Law 92-500, the U.S. Environmental Protection Agency issues guidelines, essentially legal requirements, which restrict the allowable discharge of water pollutants from given industries on a step-wise basis leading to eventual zero discharge. They are issued as National Pollutant Discharge Elimination System (NPDES) guidelines. These guidelines are based upon the discharge of pollutants from certain acceptable wastewater treatment systems, but as written they do not require the actual installation of a treatment system; only an equivalent reduction in pollutant discharge. Whether this reduction would best be accomplished by wastewater treatment or process change can be determined only by an in depth cost effectiveness analysis.

Purpose and Scope

The purpose of this paper is to present a discussion of the pollutant reduction alternatives available to the poultry processing industry, to present data relative to the technical feasibility of those alternatives and to present a method for determining the cost effectiveness of each alternative or set of alternatives. Not included in this presentation is a discussion of alternatives such as discharge to a municipal wastewater system or final treatment on site by a biological treatment system. Since the effluent from neither of these systems can be recycled and reused without still further treatment, they are not considered appropriate in a program whose ultimate goal is zero discharge.

DESCRIPTION OF POULTRY PROCESSING

A typical poultry processing plant produces defeathered and eviscerated whole and cut up chicken as outlined schematically in Figure 1. Birds are received live in crates and are hung by the feet on a moving conveying system in the receiving area. After being killed and bled they are soaked in a hot water bath called a scalder to facilitate defeathering. They are then defeathered mechanically, washed and are moved on to the evisceration area where the offal, lungs, giblets and heads are removed. After a final wash they are emersed in an ice water bath to cool the meat to approximately 37° F (2.78° C). This ice water bath, referred to as a chiller, consists of two serial operations; the pre-chiller and the second stage chiller. Water moves counter-current to the movement of the birds. The chilled birds are either packed in ice and shipped, or are further processed (cut up and/or cooked).

There are four major sources of wastewater in a typical poultry processing plant. Federal regulations require that the scalder overflow at a rate of at least 1 qt/bird/day, and that the chiller overflow at a rate of at least 2 qt/bird/day. The third major source is the viscera carriage flume, whose function is to flush the viscera away from the evisceration stations to a screen. The water in the viscera flume originates at the final bird wash station, hand wash stations and side pan wash which constantly washes down the sides of the flume to keep it clean. Approximately 360 gpm (22.72 l/sec) of wastewater flow from the viscera flume in a 12,000 bird per hour plant.

The fourth major source of wastewater that must be treated before discharge is the nightly plant washdown. The quantity of washdown water is usually about 300,000 gpd (1,135, 500 l/day).

Table 1 presents a summary of the pollutional loads from a typical 12,000 bird per hour chicken processing plant. The values listed in Table 1 are averages obtained during many days of sampling at two poultry processing plants in Maine. The total plant flow is listed as 900,000 gallons per day (gpd) (3,406,500 l/day) for a processing day during which 90,000 chickens (broilers averaging 3½ pounds live weight were killed. Experience has shown that this total flow can be reduced to as little as 700,000 gpd (2,649,500 l/day) with some reduction in total pounds of pollutants; however, the total weight of pollutant discharged does not decrease in proportion to water reduction. All of the calculations of pollutant discharge in this paper were based upon the values shown in Table 1.

Table 1 shows that the largest sources of BOD_5, suspended solids (S.S.), and grease discharge are the viscera flume and the night washdown. The viscera flume contributes 1,516 pounds of BOD_5 per day, or 38 percent of the total plant discharge of 4,002 pounds per day. In addition, it contributes 34 percent of the total S.S. load and 57 percent of the total grease load. The contribution of BOD_5, S.S., and grease from the night washdown are 1,274 lb/day (578.4 kg/day), 775 lb/day (351.85 kg/day), and 650 lb/day (295.1 kg/day), respectively, amounting to 32, 25 and 26 percent of the total.

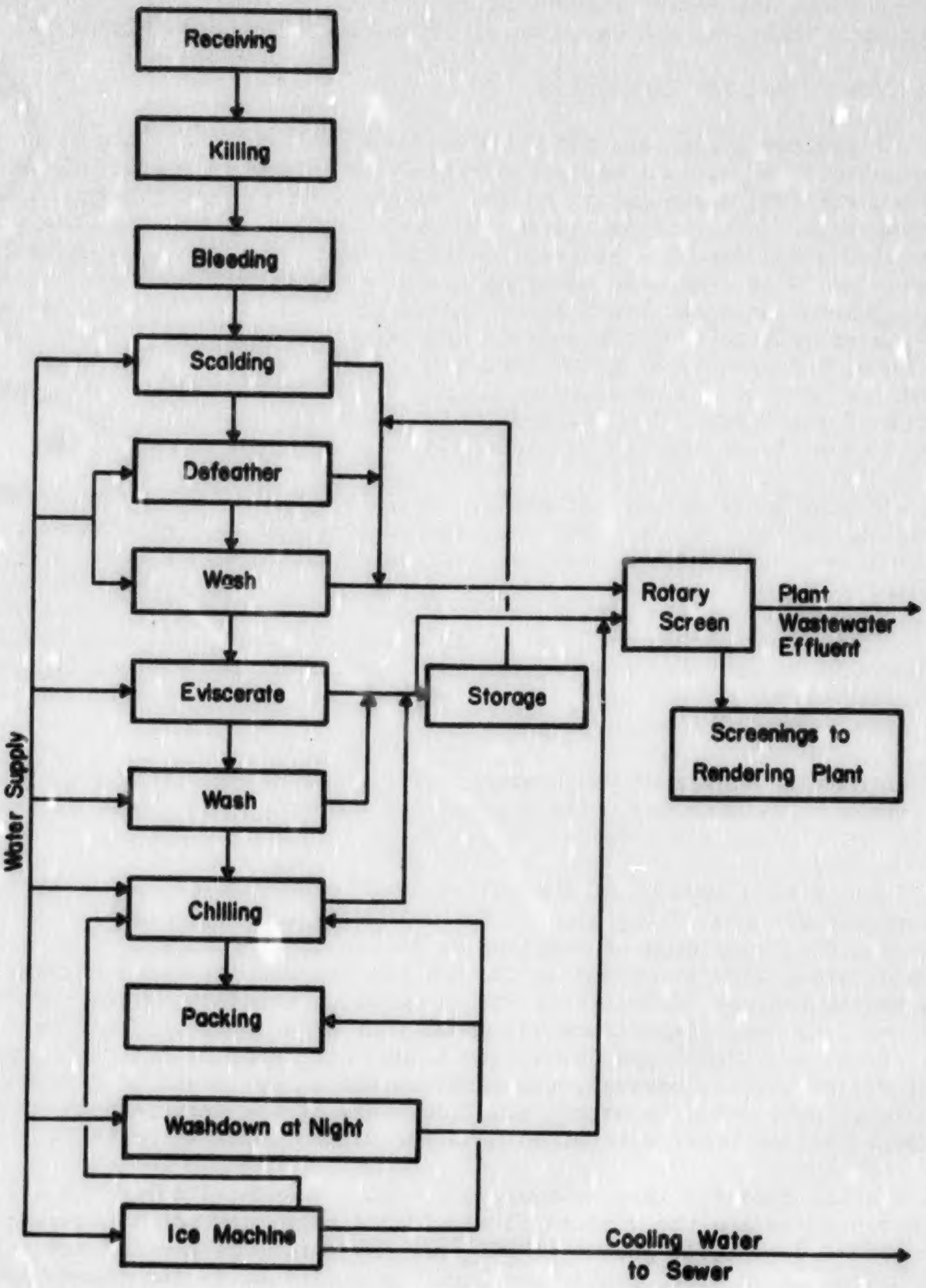

Receiving
Killing
Bleeding
Scalding
Defeather
Wash
Eviscerate
Wash
Chilling
Packing
Washdown at Night
Ice Machine
Water Supply
Storage
Rotary Screen
Plant Wastewater Effluent
Screenings to Rendering Plant
Cooling Water to Sewer

Figure 1. Schematic of a typical poultry processing plant.

TABLE 1. POULTRY PROCESSING WASTEWATER CHARACTERISTICS

System	Flow GPD	BOD mg/l	BOD lb/day	S.S. mg/l	S.S. lb/day	Grease & Oil mg/l	Grease & Oil lb/day
Total Plant	900,000	534	4,002	411	3,082	338	2,537
Visc	350,000	520	1,516	360	1,050	500	1,458
Chill Overflow & Dump	140,000	600	700	500	583	280	327
Scald Overflow & Dump	65,000	600	325	900	487	50	27
Night Washdown	300,000	510	1,274	310	775	260	650
Other	45,000	500	187	500	187	200	75

NPDES GUIDELINES

At the present time, the proposed guidelines relative to the chicken subcategory of the poultry processing industry are as follows (1):

BOD_5: 0.46 kg/kkg LWK*

Suspended Solids: 0.62 kg/kkg LWK

Grease: 0.20 kg/kkg LWK

(* LWK = live weight killed)

(kg/kkg LWK = lb/1000 lb LWK)

As mentioned previously, these guidelines are still only proposed. Whether or not these guidelines should be changed is still under consideration. It is intended that this paper will provide information which will aid in a rational decision to change these guidelines.

ALTERNATIVES FOR POLLUTANT REDUCTION

Three systems for reducing the discharge of pollutants from poultry processing plants are evaluated in this paper. A brief description of each follows:

1. Treatment of the combined wasteflows by chemical coagulation and dissolved air flotation followed by sufficient tertiary treatment to meet NPDES requirements. The tertiary treatment stages considered in this work included sand filtration followed by activated carbon adsorption.

2. Effluent flow reduction by replacement of one or more of the items of water using process equipment with non water using equipment. There are three areas where such replacement could be implemented. The first would be to replace the ice water chilling process with a cold air blast system, referred to as "dry chill". A system of this type has been in operation at one of the processing plants included in this work for several years.

A second possible alternative would be to replace the viscera removal system with a vacuum system. Several of these systems have been installed at various plants in the country, with varying degrees of success.

A third alternative which is at present only in the speculative state, would be to scald the freshly killed birds in a steam chamber rather than in the present hot water bath.

The resulting total plant effluent after one or more of the above replacements were made, would have to be treated to the extent that NPDES requirements would be met. Financial feasibility would be determined by a comparison between the cost of a given installation vs. the cost of treating the wastewater which that installation eliminated.

3. Treatment and reuse of water at each individual process. A physico-chemical

type of treatment system consisting of screening, chemical coagulation, dissolved air flotation, followed by sand filtration, activated carbon adsorption and disinfection is considered in this paper. Heat conservation should also be employed for reasons of economic as well as bacterial control.

Alternatives 2 and 3 have essentially the same purpose with respect to pollutant discharge reduction. That is simply to eliminate a water using process as a source of pollutant contribution to the total plant effluent. Table 2 shows the calculated pollutant discharge levels that could be achieved by "drying up" (using a non water using process) or "bottling up" (by treatment and recycle at the source) each of the three major water using processes.

The values presented in Table 2 were calculated as follows: It was assumed that a secondary treatment system achieving 85 percent removal of BOD_5 90 percent removal of S.S. and 95 percent removal of grease would treat the final effluent from each alternative system. It was further assumed that replacement of the viscera removal system with a dry system would remove 90% of the present pollutional load from that source, and that "drying up" the chiller and/or the scalder would remove 100 percent of the pollutional load therefrom.

Since it has been shown that dissolved air flotation incorporating chemical coagulation (DAF) is the most effective and economical system for removing 85 to 95 percent of the pollutants from poultry processing wastewater (2) (3) (4), DAF was assumed as the secondary treatment system. However, any secondary system producing 85% BOD_5 removal, 90% S.S. removal and 95% grease removal would yield the same results as those presented in Table 2 .

Table 2 shows that, based on the pollutant discharge levels presented in Table 1, the discharge of BOD_5 from a plant having all conventional water using processing equipment and having a secondary treatment system (as specified above) would be 1.91 kg/kkg LWK, 315 percent in excess of the amount allowable by the proposed NPDES requirements. The calculated discharges of S.S. and grease are 0.98 and 0.40 kg/kkg LWK, respectively, and are 58 percent and 100 percent in excess of the proposed NPDES requirements. Table 2 shows further that installation of a dry viscera removal system in conjunction with secondary treatment of the remaining total plant effluent would result in achievement of the proposed grease limitation, but that the S.S. discharge would be slightly excessive and the BOD_5 discharge would be 1.91 kg/kkg LWK, 1.45 kg/kkg LWK greater than the proposed limit of 0.46 kg/kkg LWK. Still further drying up by installation of a dry chill system would result in satisfaction of both the S.S. and grease requirements but the BOD_5 discharge would still be excessive. In fact, Table 2 shows that even after all of the major water using processes have been replaced by either a dry processing system or a treatment, recycle and reuse system, the proposed limitation for BOD_5 could not be met by ordinary secondary treatment of the remaining effluent. This fact strongly suggests that the proposed guidelines should not be promulgated.

The results shown in Table 2 do not suggest that the installation of dry processing equipment (or treatment and recycle at individual sources) is an infeasible approach. If the presently proposed guidelines were to be adopted, further wastewater treatment would have to be installed along with any one of the alternative systems listed in Table 2 . The optimum total system would

TABLE 2. EFFLUENT DISCHARGE LEVELS

Alternative Systems	(Total Discharge (kg/kkg LWK)		
	BOD_5	S.S.	Grease & Oil
No. 1 DAF Treatment alone	1.91	0.98	0.40
No. 2 DAF Treatment & dry visc	1.26	0.68	0.19
No. 3 DAF Treatment dry visc & dry chill	0.92	0.49	0.14
No. 4 DAF Treatment, dry visc dry chill & dry scald	0.77	0.34	0.14
Proposed NPDES Guideline	0.46	0.62	0.20

* Assuming that the final effluent from each alternative system is treated in a secondary plant which achieves 85 per cent removal of BOD_5, 90 per cent removal of S.S. and 95 per cent removal of grease & oil.

depend upon the lowest overall cost. For instance, even though the discharge from alternative No. 3 would have to be further treated, the total cost might be less than the cost of tertiary treatment of the larger quantity of effluent from a totally wet, conventional processing plant.

TECHNICAL FEASIBILITY

Results relating to the technical feasibility of each of the alternative systems have been published elsewhere (3) (5). Selected results are presented in this paper to illustrate (1) that achievement of the proposed NPDES guidelines is technically feasible and (2) that the expense of activated carbon adsorption is extremely high.

Tertiary Treatment of Total Plant Effluent--Table 3 shows the maximum concentrations of BOD_5, S.S. and grease which could be discharged from a plant processing 90,000 chickens per day averaging 3.5 pounds (1.59 kg) and discharging 900,000 gallons of wastewater per day (3,406,500 l/day). Figure 2 shows that the requirement for S.S. ($\leq$ 26 gm/l) can be met by sand filtration. Figure 2 shows that at loading rates of both 2 and 4 gpm/ft^2 (81.4 and 162.8 l/min sq m) effluent suspended solids concentrations were well below 26 mg/l. Figure 3 shows a column exhaustion curve obtained by passing DAF effluent through a column of activated carbon. A search of nine brands of activated carbon showed that the brand used for the exhaustion curve shown in Figure 3 produced the best exhaustion characteristics and the highest carbon loading rate (5). This carbon loading rate, however, was extremely low, and Figure 3 shows that an effluent concentration of more than 20 mg/l of TOC was observed after only 6 hours of operation at a contact time of 22.4 minutes. The cost for carbon alone for this system would be in excess of $50.00 per thousand gallons treated. Even if a carbon could be developed which was 10 times more effective for this wastewater, the cost would exceed $5.00 per thousand gallons, ten times greater than the $.50 per thousand gallon cost for DAF treatment.

Treatment and Recycle of Scalder and/or Chiller Water--Figure 4 shows a schematic of a physico-chemical system for treating and recycling chiller and/or scalder overflow. Here again, the first treatment step should be DAF (using chemical coagulation), not only because of its high performance and favorable efficiency, but also because the sludge produced can be harvested and used as a poultry or animal feed additive. The effluent from the DAF unit would be filtered through a sand, mixed media or diatomaceous earth filter for solids removal, then activated carbon adsorption would be employed to remove dissolved organics. Figures 5 and 6 show the levels of S.S. and TOC that could be achieved with this type of treatment process. Figure 5 shows that the suspended solids could be expected to be held below 15 mg/l and Figure 6 shows that the TOC could be held below 25 or 30 mg/l. Figure 6 also illustrates the poor efficiency of activated carbon adsorption for this application as far as carbon loading rate is concerned. As was the case for activated carbon treatment of the pretreated total plant effluent, the carbon loading was shown to be less than 0.01 lb of impurity per pound of activated carbon, resulting in a cost of more than $5.00 per thousand gallons.

The results presented in Figures 5 and 6 illustrate the approximate water quality that could be achieved with the physico-chemical treatment system shown in

TABLE 3. POLLUTANT DISCHARGE LIMITS*

Pollutant	Maximum Conc. for 900,000 GDP Flow
BOD_5	19
S.S.	26
Grease	8

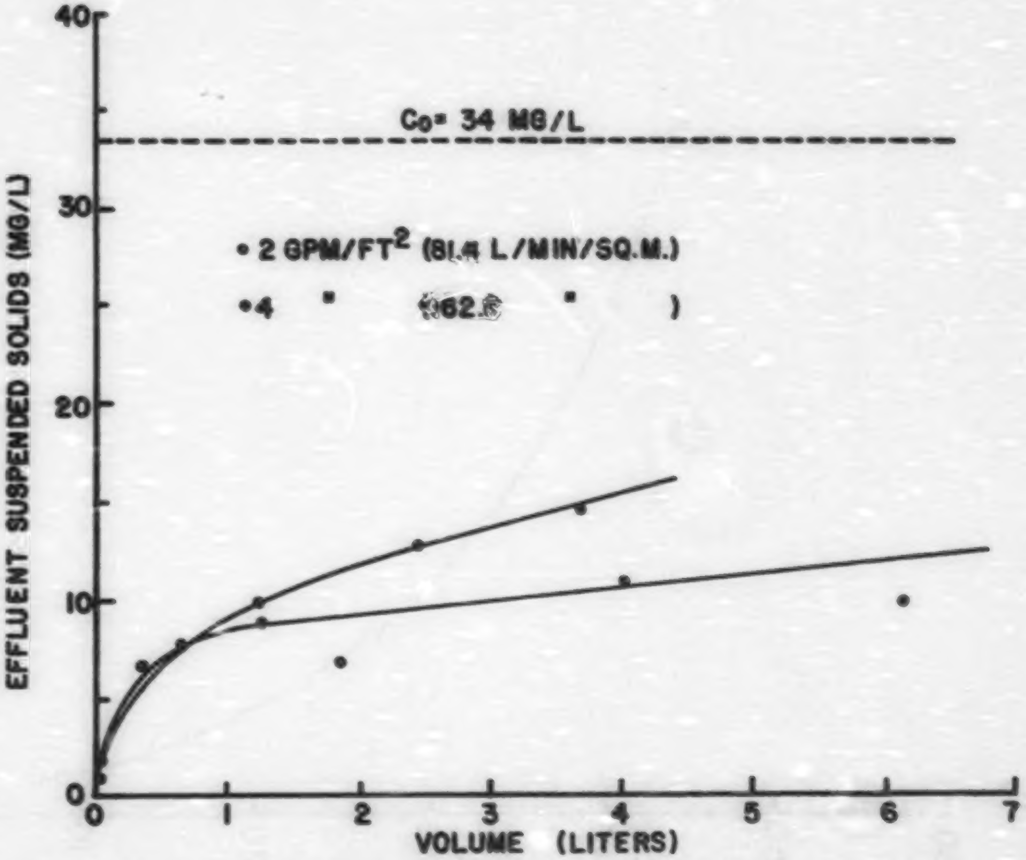


FIG.2: SAND FILTER PERFORMANCE ON DAF EFFLUENT

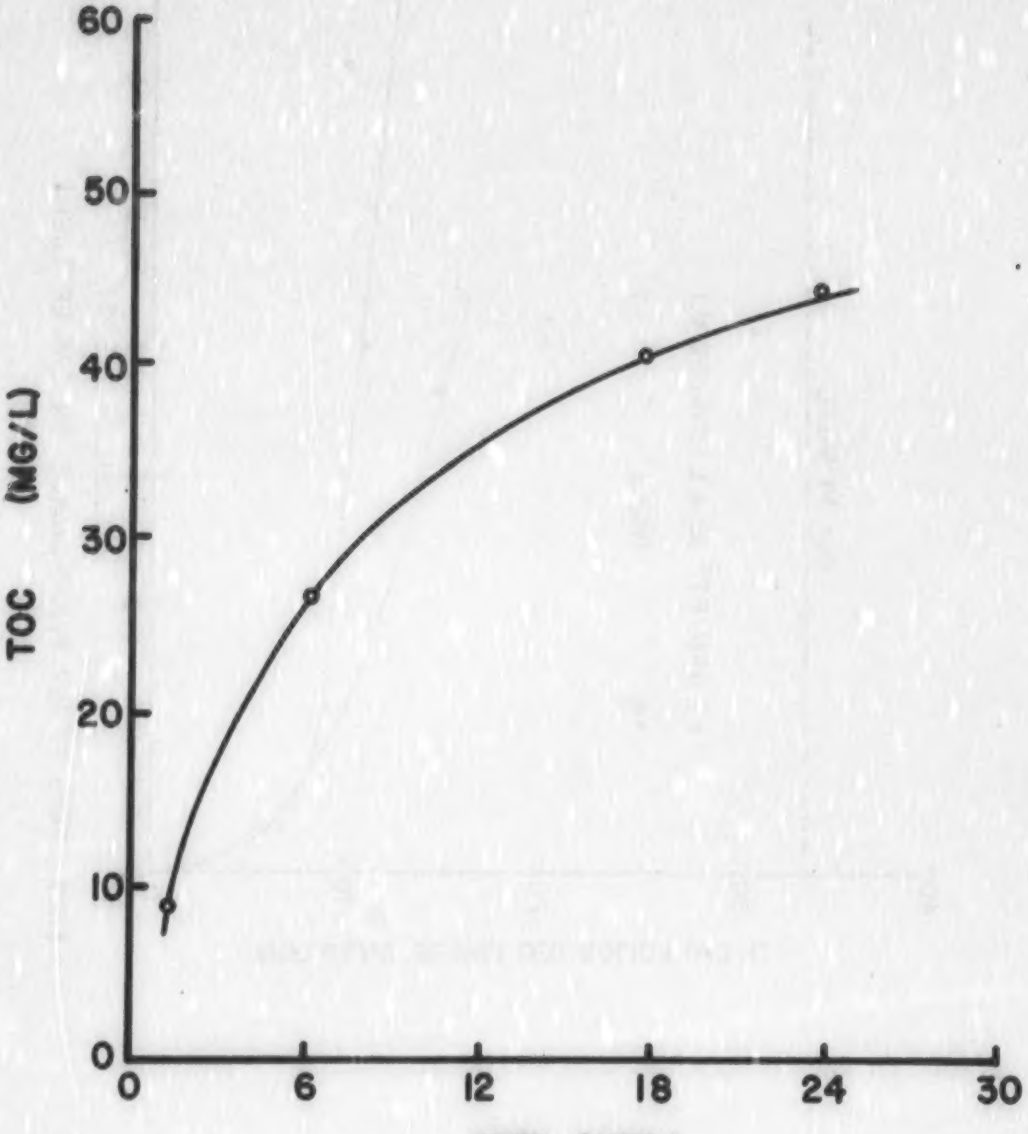


FIG. 3: COLUMN EXHAUSTION CURVE FOR DAF EFFLUENT
CONTACT TIME = 22.4 MINUTES

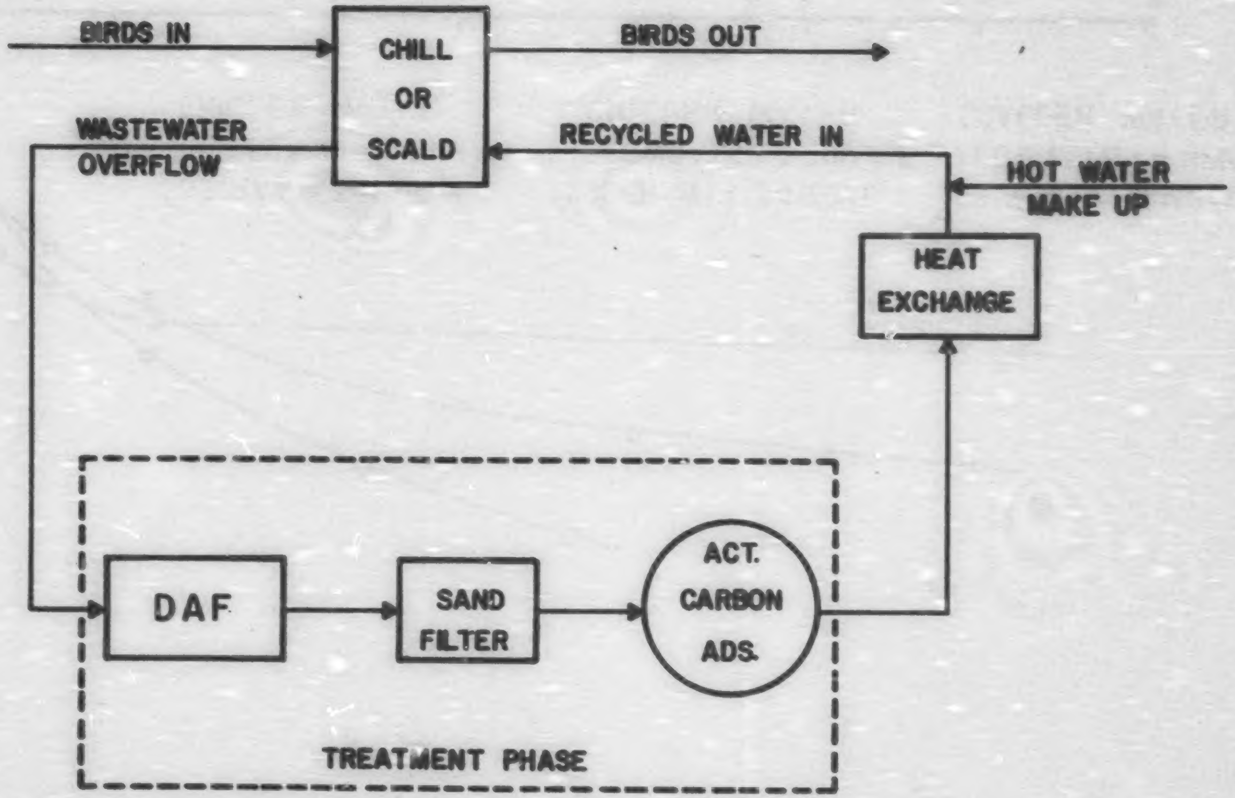

BIRDS IN
CHILL OR SCALD
BIRDS OUT
WASTEWATER OVERFLOW
RECYCLED WATER IN
HOT WATER MAKE UP
HEAT EXCHANGE
DAF
SAND FILTER
ACT. CARBON ADS.
TREATMENT PHASE

Fig. 4. Schematic of a Physico-Chemical Treatment System

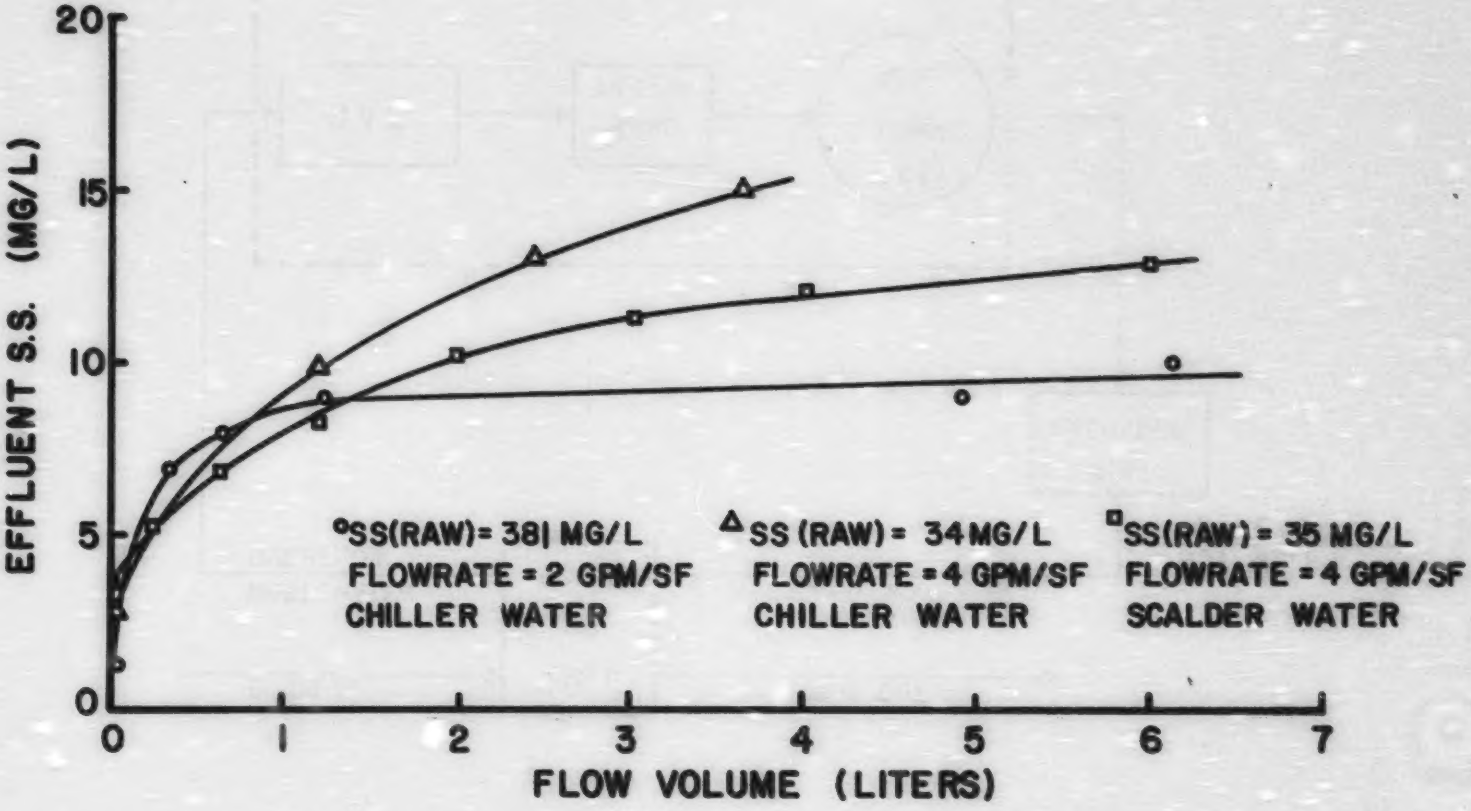


FIG.5: SAND FILTER PERFORMANCE (CHILLER & SCALDER)

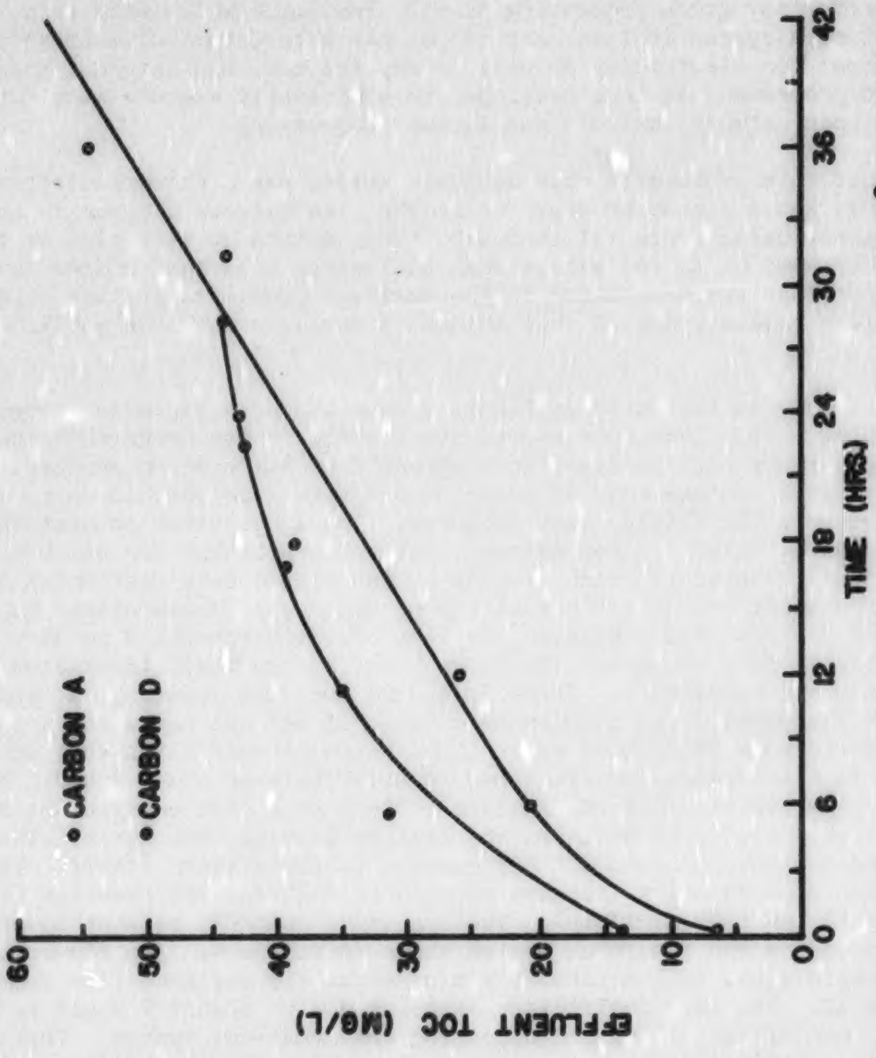


FIG.6: EXHAUSTION CURVES FOR A FLOWRATE OF 4.0 GPM/FT^2 (DAF EFFLUENT)

Figure 4. A final decision on technical feasibility could not be made until the effect of this type of system on the quality of the poultry being processed was established.

COST ANALYSIS

Once the technical feasibility of a set of alternatives has been established a cost analysis must be carried out to determine the optimum choice of alternatives for any given processing plant. Variables which will affect the total cost of a system include cost of potable water, cost of wastewater treatment and cost for electricity as well as capital cost and interest rate. A systematic procedure has been developed to efficiently execute such an analysis based upon network analysis and linear programming.

The basis of this systematic cost analysis method was a network diagram, shown in Figure 7, and a linear program for solving the network diagram in an efficient manner using a digital computer. This method is very similar to that developed by Ward et al (6) except that wastewater treatment and/or treatment, recycle and reuse are considered in the analysis presented in this paper. A more complete presentation of this method of analysis has been published elsewhere (7).

The network diagram presented in Figure 7 consists of a series of nodes numbered 1 through 22. Each node represents a state in the progress of poultry processing. Money must be spent to progress from one node to another. For instance, Figure 7 shows that in order to progress from node 10 to node 12, money to operate the chiller must be spent. The lines which connect the nodes are called arcs. Each arc represents a "stage" or process for which money must be spent. Therefore, each arc has an associated unit cost which is the cost of processing one gallon per minute of water and an associated flowrate. The network diagram thus simulates the flow of water through a poultry processing plant. Each arc shown in Figure 7 has a name which identifies the process which it represents. There is an arc for each existing and proposed process in the plant. The numbers below some of the arc names shown in Figure 7 identify the rate of flow of water through the process which that arc represents. To illustrate, the arc named SCALDINP between nodes 2 and 3 represents the pipe used to fill the scalder. There is a cost coefficient associated with this arc which reflects the cost of heating this water. The arc between nodes 3 and 16 named SCALDER represents the scalder itself. The number 50 which appears below the name represents the required overflow from the scalder of 50 gpm (189.25 l/min). The arc named SCALDTRT between nodes 16 and 17 represents the treatment system shown in Figure 4. The flowrate through this arc would equal 50 gpm (189.25 l/min) minus the assigned flow from node 16 to node 15. The cost coefficient associated with SCALDTRT would reflect the total cost of installing and operating the treatment system. This cost would include capital cost, interest charges, chemical, electrical, maintenance and manpower costs.

A linear program has been developed to "solve" the network diagram for each different set of cost coefficients and assigned flow rates. The objective function of the linear program minimizes the total system cost based on the cost coefficient and flowrate information for a given set of conditions. The

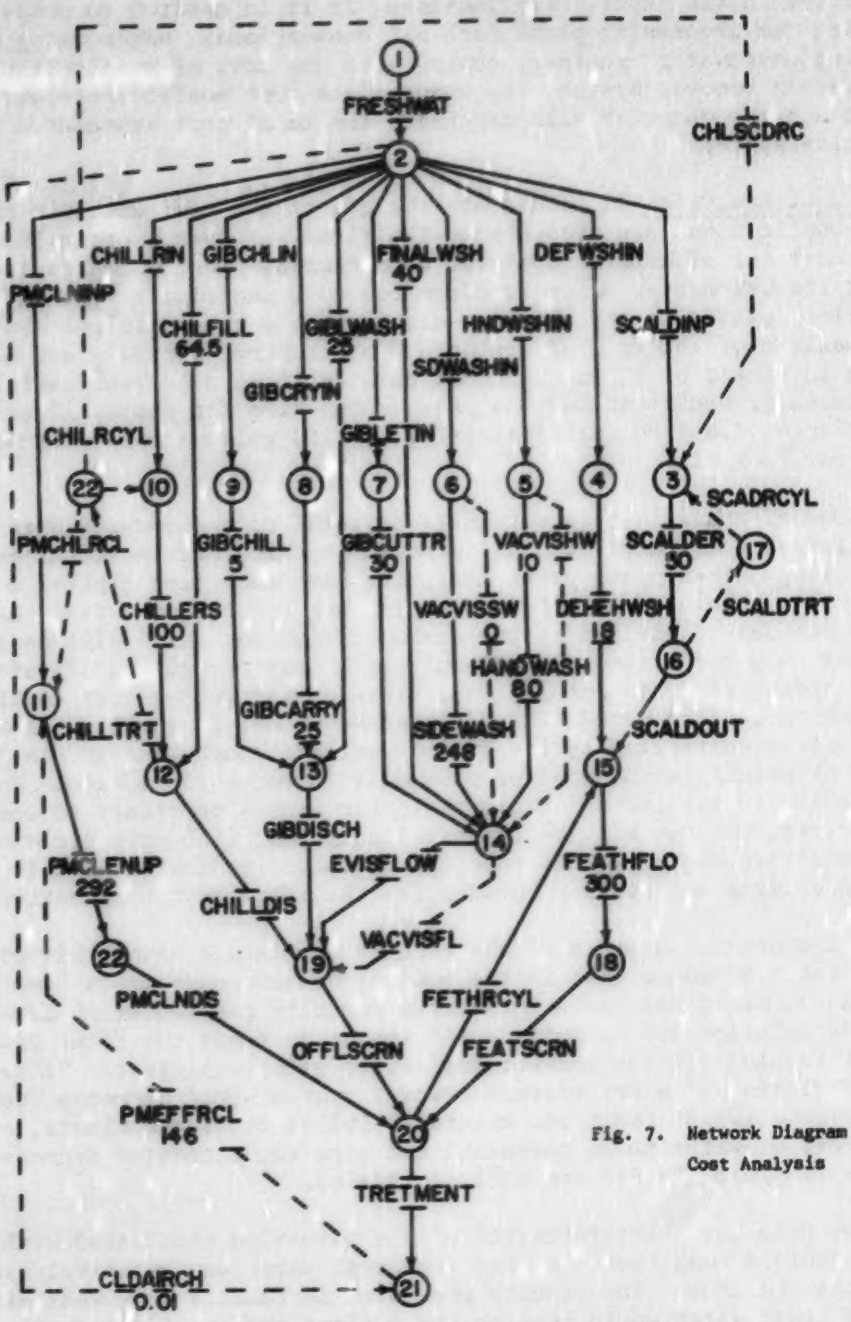

1
FRESHWAT
2
CHLSCDRC
CHILLRIN
GIBCHLIN
FINALWSH 40
DEFWSHIN
PMCLNINP
CHILFILL 64.5
GIBLWASH 25
HNDWSHIN
SCALDINP
SDWASHIN
GIBCRYIN
GIBLETIN
CHILRCYL
22
10
9
8
7
6
5
4
3
SCADRCYL
PMCHLRCL
GIBCHILL 5
GIBCUTTR 30
VACVISHW 10
SCALDER 30
17
CHILLERS 100
VACVISSW 0
DEHEHWSH 18
SCALDTRT
16
HANDWASH 80
11
GIBCARRY 25
SIDEWASH 248
SCALDOUT
CHILLTRT
12
13
15
GIBDISCH
14
EVISFLOW
FEATHFLO 300
PMCLENUP 292
CHILLDIS
VACVISFL
22
19
18
PMCLNDIS
FETHRCYL
OFFLSCRN
FEATSCRN
PMEFFRCL 146
20
TRETMENT
CLDAIRCH 0.01
21

Fig. 7. Network Diagram for Cost Analysis

output from this program is the total cost for the set of alternatives which is specified in the input. For instance, if it is desired to compare the cost of running the processing plant with all conventional, water using equipment (including wastewater treatment costs) with the cost of running the plant with a dry viscera removal system, the appropriate cost coefficients are supplied as input and the computer will calculate the total cost associated with both alternative systems.

Example Cost Analysis--To illustrate the use of the cost analysis method, two example applications are presented. The first involves a determination of the minimum cost set of alternatives for a processing plant which is required to pretreat its wastewater prior to discharge to a municipal treatment system. Restrictions placed on the effluent discharged to the municipal system include only a maximum of 100 mg/l of grease and a surcharge for BOD_5 and S.S. concentrations in excess of 300 mg/l. Cost data included a 10 year useful life for major pieces of equipment and a 5 year useful life for pumps, 10 percent interest charge, 3.6¢/KWH for electricity, 5¢/100 gallons for fresh water and 34¢/gal for fuel oil.

This method of analysis requires that the total cost for wastewater treatment be calculated separately. It is desirable to calculate the total annual cost for operating a treatment system including both amortized capital costs and operating costs. This total annual cost is then reduced to a daily cost, then the cost per day is divided by the number of gallons which will be treated in the system in a day's time. The result is a cost per gallon of water treated (usually stated as cents per gallon). This number is the cost coefficient associated with the arc named TREATMENT between nodes 20 and 21. When this cost coefficient is multiplied by the flow of water through that arc in gallons per minute, the result is the cost of treatment in cents per minute. When this cost is added to the costs for all the other arcs appropriate to one alternative system, the sum will be the total unit cost (in cents per minute) for that alternative system. This result is compared to the total unit cost for all other alternative systems to identify the least cost alternative.

Table 4 presents an example of the results obtainable using this cost analysis method. Table 4 shows that if the cost of water treatment is $.42 per thousand gallons, as it was for a DAF system for this particular application, the least cost solution was to build a DAF system to treat the total discharge from the plant keeping all the conventional water using equipment. Table 4 shows that installation of a dry viscera removal system would increase the total unit cost from 128.39 cents per minute to 132.38 cents per minute, even though the flowrate of water to be purchased and also to be treated decreased from 922 gpm (3489.77 l/min) to 697 gpm (2638.15 l/min).

One of the peculiar characteristics of the situation associated with the results shown in Table 4 was that the cost for fresh water was relatively low at $.05 per thousand gallons. The results presented in Table 5 show what effect higher costs for fresh water would have on the optimum choice of alternatives. The results shown in Table 5 show that at the current cost of $.05 per thousand gallons the increased cost resulting from use of a dry viscera removal system over the conventional water trough system would amount to $4,800 per year. If the cost for fresh water rose to $.15 per thousand gallons and every other

TABLE 4.

RANKING OF THE ALTERNATIVES

TREATMENT COST = 42¢/1000 GALLONS

ALTERNATIVES	FLOW, GPM	COST, ¢/MINUTE
# 1 Wet Sclad, Wet Vis	922	128.39
#2 Wet Scald, Dry Vis	697	132.38
#3 Dry Scald, Wet Vis	884	138.89
#7 Dry Sclad, Dry Vis	659	142.88
#4 Wet Scald, Wet Vis 100% Dry Chill	842	167.83
#3 Wet Scald, Dry Vis 100% Dry Chill	617	171.82
#5 Dry Scald, Wet Vis 100% Dry Chill	804	178.34
#6 Dry Scald, Dry Vis 100% Dry Chill	579	182.32

TABLE 5.

EFFECTS OF INCREASING COST FOR FRESH WATER

Modifications	Fresh Water Cost ¢/1000 Gallon	Yearly Amount, $	Effect
Dry Viscera Removal	5	4,800	Increase
	15	2,100	Increase
	25	600	**Decrease
Dry Scalding	5	12,700	Increase
	15	12,200	Increase
	25	11,700	Increase
100% Dry Chilling	5	47,500	Increase
	15	46,600	Increase
	25	45,600	Increase

cost stayed the same the increased cost for a dry viscera removal system would drop to $2,100 per year. If the cost for fresh water rose 10 additional cents to $.25 per thousand gallons, the alternative including the dry viscera removal system would then be less expensive than the conventional system and would save $600.00 per year. Table 5 further shows that up to a cost for fresh water of $.25 per thousand gallons, the alternative systems which include dry scalding and dry chilling remain more expensive than the conventional all wet system. A sweeping generalization to this effect cannot be made, however, since there are so many variable costs involved in the analysis which will change from the situation at one plant to another.

The results presented in Table 6 involve a different poultry processing plant. These results are included in this paper to illustrate the change in optimum system combinations caused by high costs for wastewater treatment, such as would result from the installation of a tertiary treatment system. Table 6 shows that if the total cost for wastewater treatment were $2.00 per thousand gallons, the least cost set of alternatives would include a dry viscera removal system and a conventional ice water bath chiller. Installation of a dry chilling system would result in an increased annual cost of $36,420. However, if the cost of wastewater treatment were to total $5.00 per thousand gallons, installation of the dry chilling system would result in an annual savings of $22,800.

Again it is emphasized that the results presented in Table 6 , or any set of results obtained using this cost analysis method, cannot be extended to generalized conclusions. A solution must be generated for each specific set of circumstances.

SUMMARY

The generation of water pollutants in a poultry processing plant has been discussed and an analysis made of the quantity of pollutants contributed by each major processing step. Several alternatives for reducing the discharge of pollutants from a poultry processing plant were presented, including tertiary treatment, replacement of wet processing equipment with non water using equipment and treatment, recycle and reuse of chiller and chiller overflow water. The technical feasibility of both tertiary treatment to meet proposed NPDES guidelines was demonstrated but was shown to involve extremely high cost. In addition, the characteristics of treated chiller water using DAF, sand filtration and activated carbon adsorption were presented. A systematic method for determining the least cost set of alternative methods for reducing pollutant discharge to a given level was discussed. Example solutions showed that local situations involving the cost of fresh water and wastewater treatment costs greatly influence the choice of optimum system configuration.

TABLE 6.

EFFECTS OF HIGH
COSTS FOR TERTIARY
TREATMENT

Rank	Combination	Total Cost ¢/min	Total Flow gpm	Annual Cost Above 1st Ranked Comb. $
	Tertiary Treatment cost = $2.00/1000 gal.			
1	Vacuum Viscera & Water Chill	230.935	661.5	-
2	Vacuum Viscera & Cold Air Chill	261.284	497.0	36,420
3	Existing Viscera & Water Chill	292.101	979.5	73,400
4	Existing Viscera & Cold Air Chill	322.130	815.0	109,440
	Tertiary Treatment cost = $5.00/1000 gal.			
1	Vacuum Viscera & Cold Air Chill	410.384	497.0	-
2	Vacuum Viscera & Water Chill	429.385	661.5	22,800
3	Existing Viscera & Cold Air Chill	566.630	815.0	187,495
4	Existing Viscera & Water Chill	585.951	979.0	210,680

CONCLUSIONS

1. As presently proposed, the NPDES discharge guidelines for the chicken processing industry can be met only by:

    a. Tertiary treatment of the entire wastewater flow using sand filtration and activated carbon adsorption.

    b. Replacement of all of the major processing units with non water using equipment.

    c. Extensive biological treatment.

    All three of the above alternatives must be preceded or accompanied by dissolved air flotation incorporating chemical coagulation.

2. A cost analysis has shown that:

    a. The cost for tertiary treatment using sand filtration and activated carbon adsorption is unreasonably high.

    b. Unless the cost for potable water and wastewater treatment are relatively high, the only feasible dry replacement process is dry viscera removal.

3. The cost feasibility of dry chilling depends upon a higher market value of the product.

4. NPDES guidelines should be modified to allow use of cost effective and energy conservative treatment commensurate with receiving water quality.

5. Dissolved air flotation incorporating chemical coagulation is capable of producing a relatively clean effluent which will not result in significant water quality degredation in many discharge locations. The cost for DAF treatment is minimal compared to the present cost for systems which would produce a significant improvement in pollutant discharge level. Therefore, dissolved air flotation in conjunction with sufficient chemical coagulation and screening to produce an overall removal of 90% BOD_5, suspended solids and grease should be adopted as best practical treatment (BPT) technology for the poultry processing industry.

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PROCESSING EGG BREAKING PLANT WASTE

by

J. M. Vandepopuliere*, H. V. Walton*, W. Jaynes* and O. J. Cotterill*

INTRODUCTION

The egg breaking industry is faced with an increasingly serious waste disposal problem. The Egg Products Inspection Act (84 Stat. 1620 et. seq., 21 U.S.C. 1031-1056) was enacted December 29, 1970. On July 1, 1972 phase two of this act became effective, controlling restricted shell eggs (checks, dirties, leakers, incubator rejects, inedibles and loss eggs). All of these types of eggs except checks and dirties must be denatured or destroyed at the point of segregation to eliminate them from consumer food channels.

There are approximately 150 egg breaking plants in the United States. These plants yield some 50,000 tons of waste annually. The current method of disposing of these wastes is either landfills or farm land pastures. It is becoming very difficult to dump this type of material in landfills or spread on pastures due to the potential pollution problems.

Basic work has been reported by Walton et al.(1) on the chemical composition of egg breaking plant wastes. This work demonstrated that there were significant levels of calcium and protein present. The nutritional value when fed to laying hens, was reported by Vandepopuliere et al.(2) to be comparable to the nutrients that were replaced from feedstuffs normally used in laying diets.

METHODS

Funds were obtained from the Environmental Protection Agency and the Missouri Agricultural Experiment Station to set up a waste processing system at a commercial egg breaking plant (Figure 1). Various types of dehydrating and

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*University of Missouri, Columbia, Missouri

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cooking equipment were investigated. A used Heil SD 45-12 became available and it was purchased. It is a triple pass rotary drum dehydrator with controls to modulate the gas flame for control of the furnace temperature and the final product temperature. The unit was installed in line in an egg breaking plant (Figure 2).

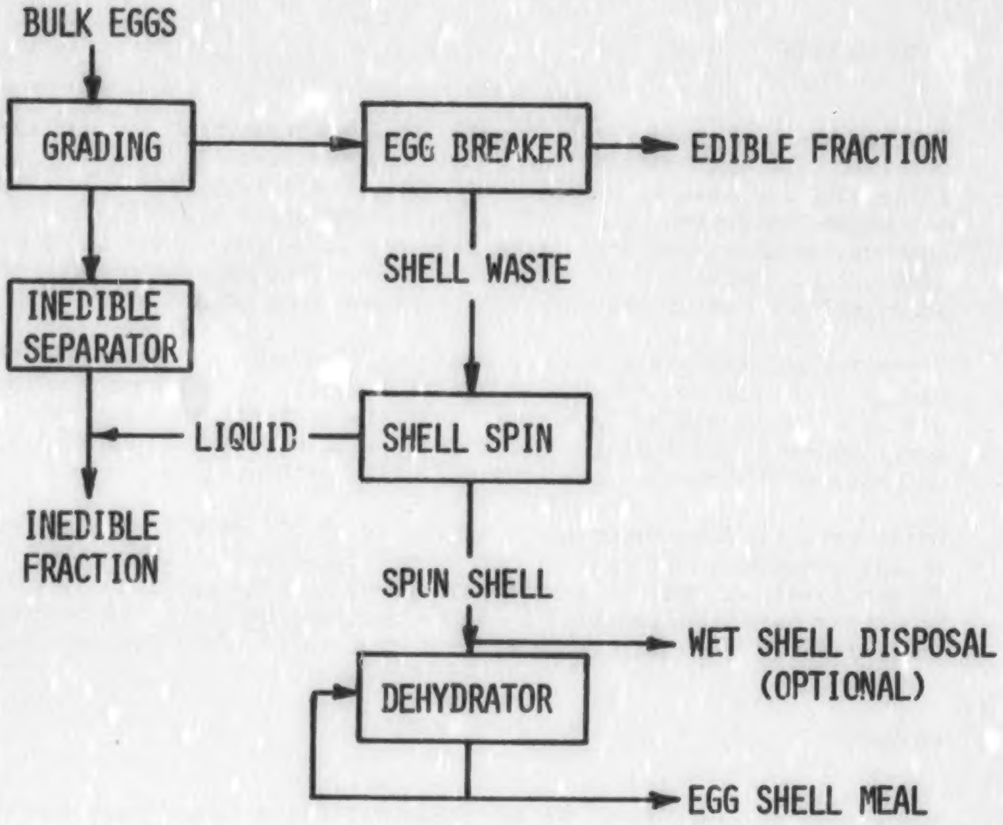

BULK EGGS
GRADING
EGG BREAKER
EDIBLE FRACTION
INEDIBLE SEPARATOR
SHELL WASTE
LIQUID
SHELL SPIN
INEDIBLE FRACTION
SPUN SHELL
WET SHELL DISPOSAL (OPTIONAL)
DEHYDRATOR
EGG SHELL MEAL

Figure 1. Egg Breaking Plant Material Flow Diagram Showing Arrangement for Shell Waste Dehydration Study.

Figure 2. Triple Pass Rotary Dehydrator

Figure 3. Cyclone Collector with Diverter to Dehydrator

During the first few days of operation a problem developed with liquid egg adhering to the hot drum. It was necessary to obtain additional equipment to remove the superficial liquid from the wastes. A shell spin was obtained from Seymour and placed in the production line. A special liquid egg (tanner) separator was designed and constructed to handle the liquid from the inedible eggs that could not be conveyed to the shell spin.

There were numerous logistic problems involved in setting up to process egg plant wastes in a plant that was on stream. It was necessary to set up dual systems and diverters to permit the wastes to go directly to the disposal carrier or be diverted to the dehydrator. This was accomplished by installing extra augers and slides.

To prevent the wet egg shells from sticking to the hot drum it was necessary to blend in some of the dried egg shell meal. An auger was used to blend egg shell meal with the unprocessed waste shells and convey the product to the dehydrator. The cyclone collector was equipped with a diverter (Figure 3) to regulate the amount of dehydrated egg shell meal that would be returned for the blending operation.

DISCUSSION AND SUMMARY

The wet egg shell waste contained approximately 17.9 X 10^5 microorganisms per gram. Samples were collected asceptically after dehydration. The total number of microorganisms (Trypticase Soy Broth) surviving each process temperature is shown in Figure 4. The total count decreased logarithmically with increased temperature. The counts for the two trials after processing at 140°F averaged about 5.6 X 10^5 per gram. At an exhaust temperature of 260°F the counts decreased to about 70 per gram. All dehydrated samples were salmonellae negative (AOAC, 1975).

TABLE 1. COST OF DEHYDRATOR OWNERSHIP BASED ON AN INSTALLED COST OF $35000

Cost Item	Depreciation Period 10 yr	20 yr	30 yr
Annual depreciation	$3500.00	$1750.00	$1166.67
Annual interest (8% of avg. invested)	1400.00	1400.00	1400.00
Maintanance and Repair (2% of cost, annually)	700.00	700.00	700.00
Insurance and Taxes (2% of cost, annually)	700.00	700.00	700.00
Annual Cost of Ownership	$6300.00	$4550.00	$3966.67
Cost/day of operation (250 days/yr)	$ 25.20	$ 18.20	$ 15.87

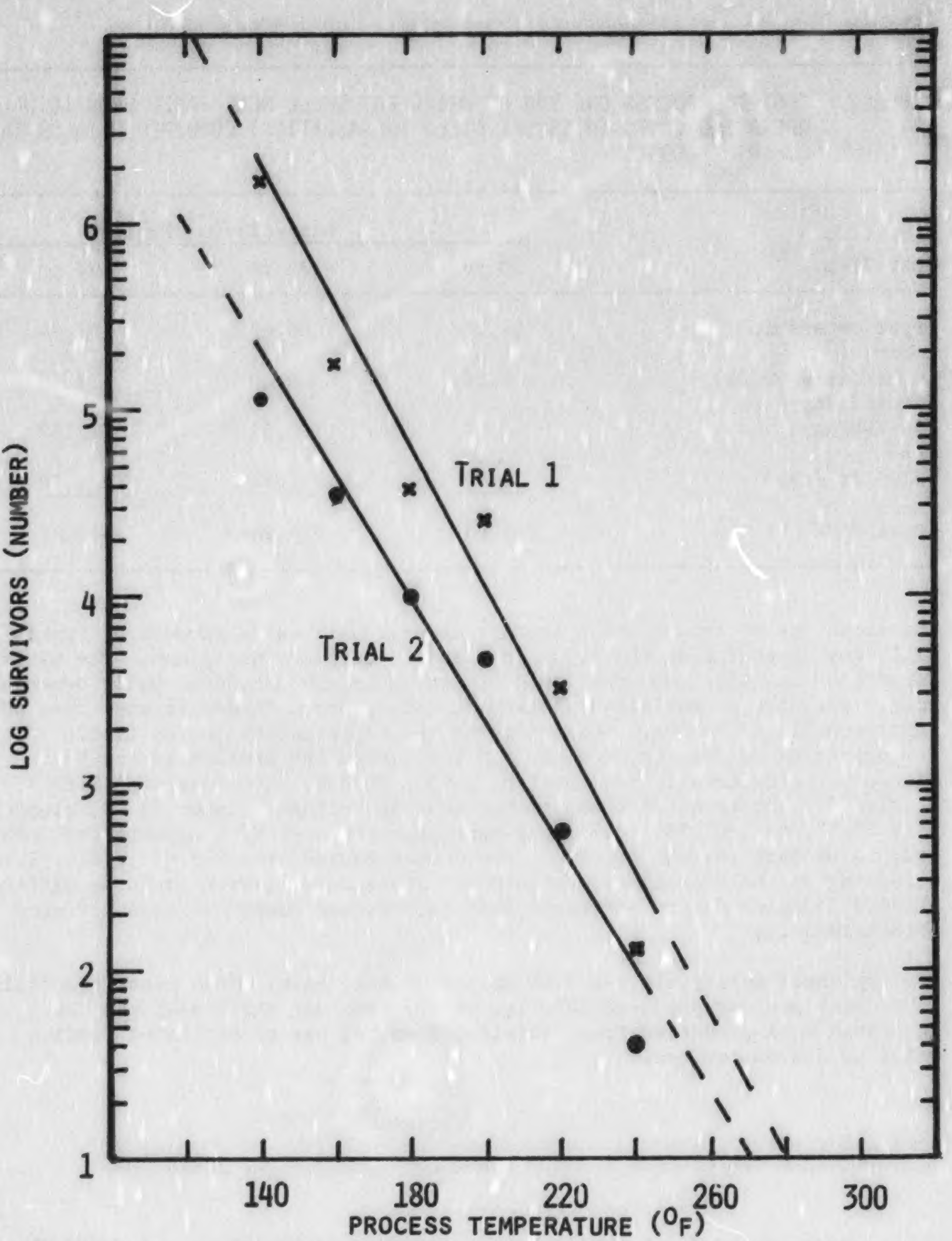


Figure 4. Destruction of Microorganisms in Egg Breaking Plant Waste during Dehydration at Various Temperatures.

TABLE 2. COST TO PROCESS ONE TON OF DRIED EGG SHELL MEAL BASED UPON ACTUAL OPERATING COSTS (MISSOURI FIELD INSTALLATION) COMBINED WITH DRYER OWNERSHIP COSTS

Cost Item	Depreciation Period		
	10 yr	20 yr	30 yr
Dryer ownership	$9.16	$6.62	$5.77
Labor (4 hr/day @ $3.65)	5.30	5.30	5.30
Electricity (58 KWH/day)	.57	.57	.57
Gas (5100 ft^3/day)	1.76	1.76	1.76
Total Cost per ton	$16.79	$14.25	$13.40

The economics of owning and operating an egg shell waste processing system will vary depending on the type and size of equipment and plant. The minimum dehydrator installation cost would be approximately $35,000. Daily ownership cost, including depreciation; interest, maintenance, insurance and taxes would vary from $15.87 to $25.20 depending on the depreciation period (Table 1). The operating cost to produce one (1) ton dried egg shell meal in the Missouri field installation breaking 1400 - 30 doz. cases/day was $7.63 (Table 2). The total cost was broken down as follows: labor $5.30, electricity $0.57, gas, $1.76. Combining ownership and operating expense the total cost to produce one ton dried egg shell meal ranged from $13.40 to $16.79 depending on the depreciation schedule. These cost figures could be different at each location due to different cost factors and number of cases of eggs processed daily.

Dry egg shell meal yield was 3.85 lb per 30 doz. case. This plant processing 1400 cases per day produced 5390 lb. or 2.7 tons egg shell meal per day. Egg shell meal processed from centrifuged wastes has an estimated feeding value of $35.00 per ton.

1. **WALTON, H. V., COTTERILL, O. J. and VANDEPOPULIERE, J. M. Composition of shell waste from egg breaking plants. Poultry Science 52: 1836 (1973).**

2. **VANDEPOPULIERE, J. M., WALTON, H. V. and COTTERILL, O. J. Nutritional value of egg shell meal. Poultry Science 54: 131 (1975).**

WATER USAGE IN POULTRY PROCESSING - AN EFFECTIVE MECHANISM FOR BACTERIAL REDUCTION

F. A. Gardner and F. A. Golan
Poultry Science Department
Texas Agricultural Experiment Station
College Station, Texas

INTRODUCTION

During the past decade, consumer groups, federal regulatory and inspection agencies, industry groups and private organizations have continuously stressed the need for strict control of poultry product quality from areas of production to the final marketing of the finished product. Product quality includes chemical, physical, functional organoliptic and microbiological characteristics of the product which are of concern to the poultry user. Awareness of product quality has generated a critical need for efficient and economical program components for quality assurance programs. A sound quality assurance program is now an essential part of all poultry processing operations and can no longer be considered an extraneous process operation. Sound, efficient and effective quality assurance programs must be financially rewarding and of necessity must be based on a thorough understanding of fundamental attributes of poultry processing. An effective assurance program must include selected microbiological characteristics of the product as essential components of the overall program. Recent concern for what some have considered to be excessive water use in poultry processing has forced an evaluation of the need for water in all areas of processing.

OBJECTIVES

The study reported in the paper was designed (1) to determine the effects of selected processing functions on the bacterial content of poultry carcasses, (2) to establish what might be considered microbiological "working normals" for poultry processing, (3) to determine the effects of water usage in processing on the microbiological characteristics of poultry and (4) to develop processor awareness of the microbiological concepts involved in processing poultry.

EXPERIMENTAL DESIGN

The data presented in this study was obtained from five chicken broiler processing plants and four turkey processing plants in Texas. Samples were collected from each of the plants on two separate days. On each sampling day selected water samples were taken prior to the start of the day's operation and again after four or five hours of continuous processing. When sampling from the turkey processing plants, selected equipment surfaces were sampled prior to the start of the day's processing and again after five hours of continuous processing. Broiler and turkey carcasses were taken at pre-determined stations and were sampled by swabbing a defined area of the breast surface. Water and equipment samples were analyzed to establish the total bacterial plate count (35°C incubated for 2-3 days), and total coliform count. In addition, samples from the turkey processing plants were analyzed for mold and yeast. Carcass samples were subjected to analysis for these parameters and for Salmonella. The sampling schedule used in turkey processing plants is summarized in Table 1. All samples were held in a slush ice environment for transportation to the Product Technology Laboratory at Texas A&M University where all microbiological analyses were performed.

RESULTS

Initial studies conducted at several participating turkey plants in this study have indicated that surface bacterial concentrations were highest on the initial carcasses processed each day and decreased during the first hour of processing (Figure 1). No further changes in bacterial concentration were noted during an additional four hour sampling period. As a result of this finding, carcass samples were not taken during the initial 60 minutes of processing.

The data which follows presents only overall means obtained from equipment, water and carcass sample analyses. No attempt has been made to present an overall plant comparison or to compare individual plants to plant processing variations.

WATER SAMPLES

Analyses of water samples taken prior to the start of the day's processing and again after five hours of continuous processing indicate a rather extensive buildup of mesophiles, coliform, mold and yeast in almost all turkey processing plant sampling areas. Exceptionally large increases were noted in the scald water and in the picker drain water samples indicating the effective carcass washing action of both systems (Table 2). It should be noted that scald water containing bacterial populations in excess of one million organisms per milliliter retained its ability to effectively wash bacteria from the turkey carcass. Scald and picker water samples taken prior to the start of processing contained relatively high bacterial concentrations indicating the need for more effective down-time sanitation programs.

Coliform concentrations in scald water samples raemained at relatively low levels during processing due primarily to the effects of the high scalding temperature generally used (Table 3). Coliform concentration increases obtained in all chill waters during processing indicates the effective washing action of these systems. The relatively high concentration of coliform obtained initially from the picker drain water samples again suggests the need for additional emphasis on down-time sanitation programs.

Mold and yeast in water samples were detected in low concentrations only (Table 4). Small, but significant increases were obtained in the mold and yeast content of both chill tank samples and in the picker drain water samples after five hours of processing. These results again suggest

TABLE 1. SAMPLING SCHEDULE FOR EACH SAMPLING DAY

Carcass Sampling Stations

Pre-scald
Post-scald
Post-picker
Enter-evisceration
Pre-viscera pull
Post-viscera removal
Pre-wash
Post-wash
Pre-chill
Post-chill
Post-drain
Pre-shrink

Equipment Sample Location*

Dressing-Evisceration Transfer Chute
Trussing Table
Chill Tank Exit Chute
Post Drain Table
Giblet Belt
Carcass Bagging Belt

Water Samples Location*

Scald Tank Water
Chill Tank #1 Water
Chill Tank #2 Water
Giblet Chill Water
Picker Drain Water

*Samples taken initially and after 5 hours of continuous processing.

Figure 1.

Surface Bacterial Counts as Affected by Hours of Continuous Processing (Samples taken Pre-Truss)

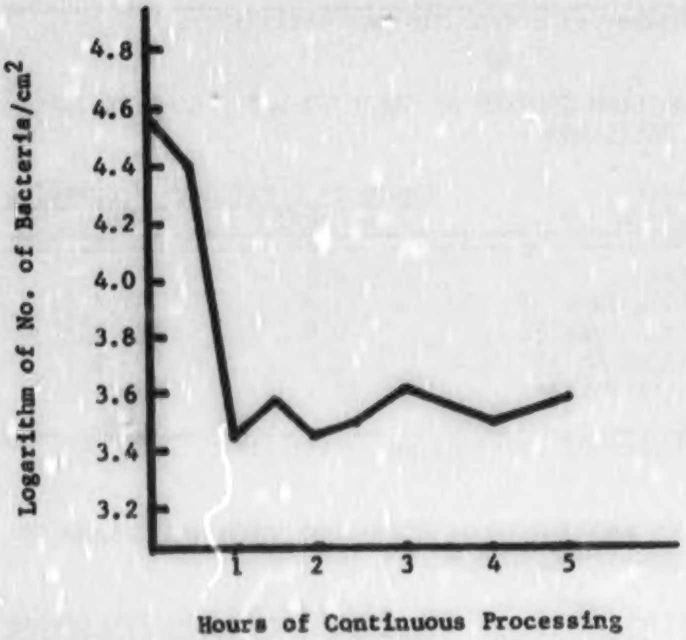


TABLE 2. MESOPHILIC BACTERIAL CONTENT OF SELECTED WATER SAMPLES TURKEY PROCESSING*

Water Sample	Hours of Continuous Processing 0 Hours	5 Hours
Scald	3,220	1,510,000
Chill Tank #1	388	31,600
Chill Tank #2	129	10,200
Giblet Chill	430	20,100
Rough Picker	970	149,000

*Number of mesophiles per milliliter.

TABLE 3. COLIFORM CONTENT OF SELECTED WATER SAMPLES TURKEY PROCESSING*

Water Sample	Hours of Continuous Processing 0 Hours	5 Hours
Scald	0.6	1.5
Chill Tank #1	1.2	151.4
Chill Tank #2	0.6	59.7
Giblet Chill	0.7	23.9
Rough Picker	55.7	830.1

*Number of coliform per milliliter.

TABLE 4. MOLD AND YEAST CONTENT OF SELECTED WATER SAMPLES TURKEY PROCESSING*

Water Sample	Hours of Continuous Processing 0 Hours	5 Hours
Scald	0.4	1.7
Chill Tank #1	1.7	93.4
Chill Tank #2	1.2	27.4
Giblet Chill	12.3	9.1
Rough Picker	9.5	47.0

*Number of mold and yeast per milliliter.

the effective carcass washing action of these systems. Mold and yeast concentrations in the scald water samples remained at low levels due primarily to the adverse effects of the scalding temperatures used. The relatively low concentration of mold and yeast detected in giblet chill water after five hours of processing indicates that the giblets do not serve as a source of these microorganisms.

Scald water samples obtained from the five broiler processing plants indicated that in most cases clean-up during the overnight "down" period did not effectively reduce bacterial numbers (14,900 per milliliter immediately post clean-up). Continuous processing for a four hour period resulted in an increase in total count and a build up of fecal coliform (Table 5).

Samples taken from both the first and third chill tanks in each of the plants indicate a relatively effective clean-up operation during the normal "down" periods (Table 6). Fecal coliform were found in concentrations of less than one per milliliter and total mesophilic bacteria were found in concentrations of about 400 per ml prior to processing. As expected concentrations of both fecal coliform and mesophilic organisms increased during processing. The combined effects of the rinsing action of the chill waters and the normal counter flow directional system of the chill tanks water on bacterial concentrations can be seen by comparing the first and third tank data following four hours of continuous processing. Bacterial concentrations of water samples from the first chill tank are double those obtained from samples taken from the third chill tanks.

EQUIPMENT SAMPLES

Analyses of equipment samples taken in turkey processing plants prior to the start of the day's processing suggest that in almost all cases microbiological concentrations appear only in limited numbers (Tables 7, 8, and 9). The primary exception to this generalization is the dressing-evisceration transfer chute where relatively high concentration of mesophiles, mold and yeast were obtained indicating the need for additional down-line sanitation emphasis in this area. During the five hour processing period, the concentration of mesophilic bacteria, coliform, mold and yeast generally increased on surfaces where water was not used as a rinse or from normal tank overflow. This increase was particularly noticeable on the dressing-eviscerating transfer chute, the trussing table, and to a lesser extent on the post drain table. These results again suggest the need for improvements in equipment design which would permit a continuous surface washing action. Bacterial numbers on the chill tank exit chute and the giblet belt remained at relatively low levels during the five hour processing period. This effect can generally be attributed to the constant flow of water over the equipment surface and/or the low bacterial concentrations generally detected on the product at these locations.

CARCASS SAMPLES

Swab samples taken from the breast area of broiler carcasses at selected processing stations were analyzed for both total mesophilic

TABLE 5. BROILER PROCESSING SCALD WATER ANALYSIS*

	Fecal Coliform	Mesophiles
Pre-processing	1.0	14,900
4 hours continuous processing	1310	2,680,000

*Geometric mean - bact/ml

TABLE 6. BROILER PROCESSING CHILL WATER ANALYSIS*

	Fecal Coliform	Mesophiles
Pre-processing		
1st chill tank	1.0	394
3rd chill tank	1.0	441
4 hours processing		
1st chill tank	857	24,100
3rd chill tank	372	12,300

*Geometric mean - bact/ml

TABLE 7. MESOPHILIC CONCENTRATIONS ON SELECTED EQUIPMENT SURFACES*

Sample Location	Hours of Continuous Processing	
	0 Hours	5 Hours
Dressing-Evisceration Transfer Chute	264	1,150
Trussing Table	15	163
Chill Tank Chute	54	15
Post Drain Table	62	108
Giblet Table	112	156
Bagging Belt	143	164

*Number of mesophiles per cm^2.

TABLE 8. COLIFORM CONCENTRATION ON SELECTED EQUIPMENT SURFACES*

Sample Location	Hours of Continuous Processing	
	0 Hours	5 Hours
Dressing-Evisceration Transfer Chute	21	357
Trussing Table	21	483
Chill Tank Chute	12	14
Post Drain Table	12	49
Giblet Table	25	19
Bagging Belt	21	19

*Number of coliform per 100 cm^2.

TABLE 9. MOLD AND YEAST CONCENTRATIONS ON SELECTED EQUIPMENT SURFACES*

Sample Location	Hours of Continuous Processing	
	0 Hours	5 Hours
Dressing-Evisceration Transfer Chute	73	24
Trussing Table	30	96
Chill Tank Chute	38	21
Post Drain Table	29	75
Giblet Table	31	30
Bagging Belt	33	42

*Number of mold and yeast per 100 cm^2.

bacterial concentration and for fecal coliform content. Overall results indicate a statistically significant reduction in total mesophilic counts associated with the processing operation (Figure 2). Separation of means by specific processing function indicates that reduction in bacterial concentration in all cases can be attributed to the rinsing effect of water used in processing (scald, wash, chill). The most significant reduction in surface counts can be attributed to the washing action of the chill system. Fecal coliforms were obtained from carcass surface samples at all processing stations. Increase in fecal coliform surface counts were associated primarily with the mechanical pickers in the dressing operation and with the viscera pulling operation during evisceration. However, the data suggest that the fecal coliform are only loosely attached to the skin since they were effectively removed by both the washing and chilling operations.

Analyses of turkey carcass samples obtained from the twelve processing stations show clearly the total bacterial reduction effects of the scalding, packing, washing and chilling operations (Figure 3). These data indicate that microbiological reductions on carcass surfaces are obtained only at processing stations where water is in constant use either as a spray or a dip. Total mesophilic bacteria on the turkey carcass were reduced in the dressing operation as a result of the scalding action, the washing action of picking and the on-line washers generally found prior to carcass transfer to the eviscerating line. Bacterial concentrations on the carcass increased during the eviscerating operation and during the handling of carcasses normally associated with carcass trussing, draining and packaging. The on-line washing operation and the liquid chilling operation significantly reduced bacterial numbers.

Coliform numbers on carcass surfaces were almost eliminated by the temperatures normally associated with the scalding operation (Figure 4). However, during picking and evisceration the concentration of surface coliform increased at a fairly constant rate. The increase can in all probability be associated with the extensive carcass handling required by the eviscerating operation. The data suggests, however, that coliform organisms are only loosely attached to the carcass surface since they were effectively removed by both the washing and chilling operations. A slight increase in coliform numbers can generally be attributed to the handling necessary for carcass trussing. However, the liquid chilling operation effectively reduced the coliform content to negligible numbers and only a slight increase was obtained during the draining and bagging operations. These results suggest that emphasis on individual worker hygiene programs would be one of the more effective methods for reducing coliform concentration on the turkey carcasses during evisceration. Additionally, the need for equipment improvements which would permit more effective removal of viscera is indicated. As stated earlier, a continuous equipment surface rinsing for the trussing operation appears warranted.

Mold and yeast on the carcass surfaces were generally detected in relatively low concentrations (Figure 5). The scalding, washing and chilling operations all contribute to reductions in saprophytic concentrations on the turkey carcass. Operations which require carcass handling

Figure 2

Mesophilic and coliform bacteria/cm^2 of surface area from carcasses sampled at each of 11 processing stations - "working normal"

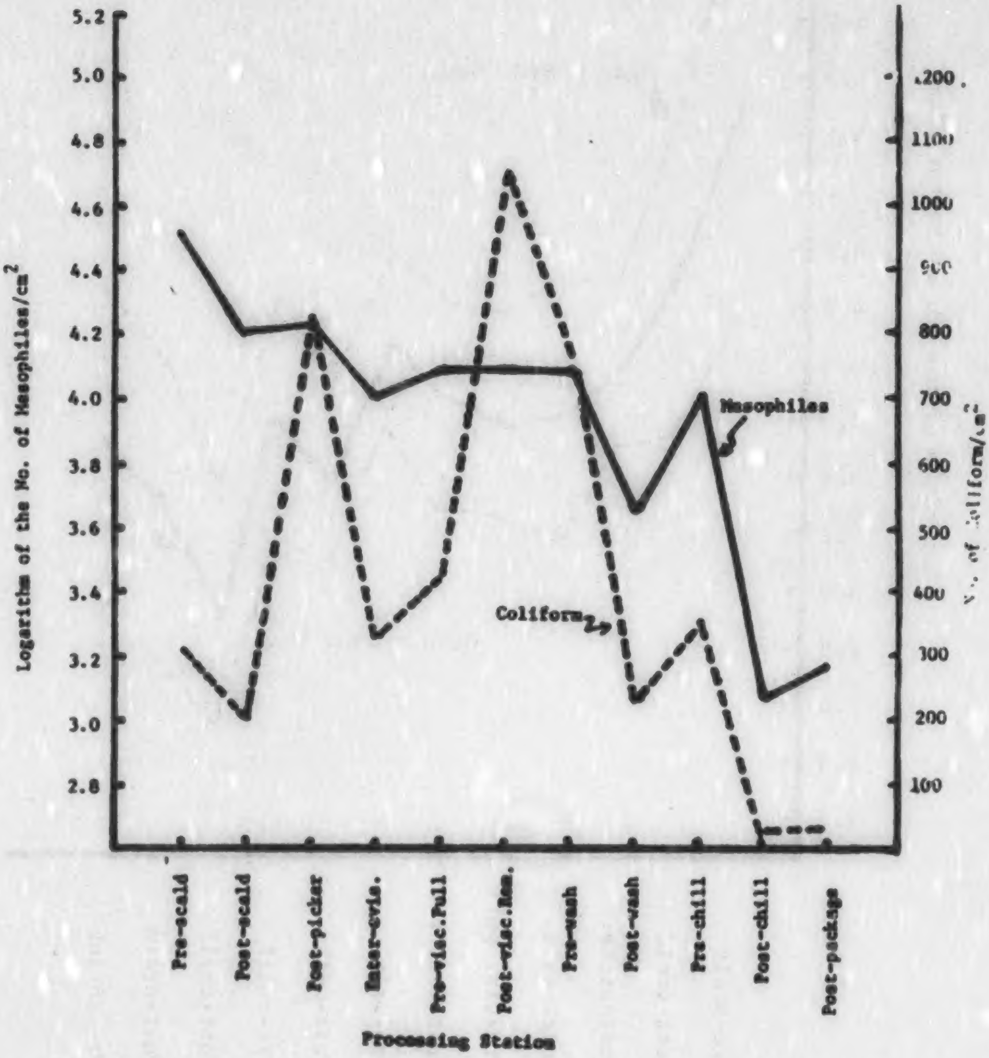


Figure 3

Mesophilic Bacteria obtained from turkey carcasses sampled at 12 processing stations

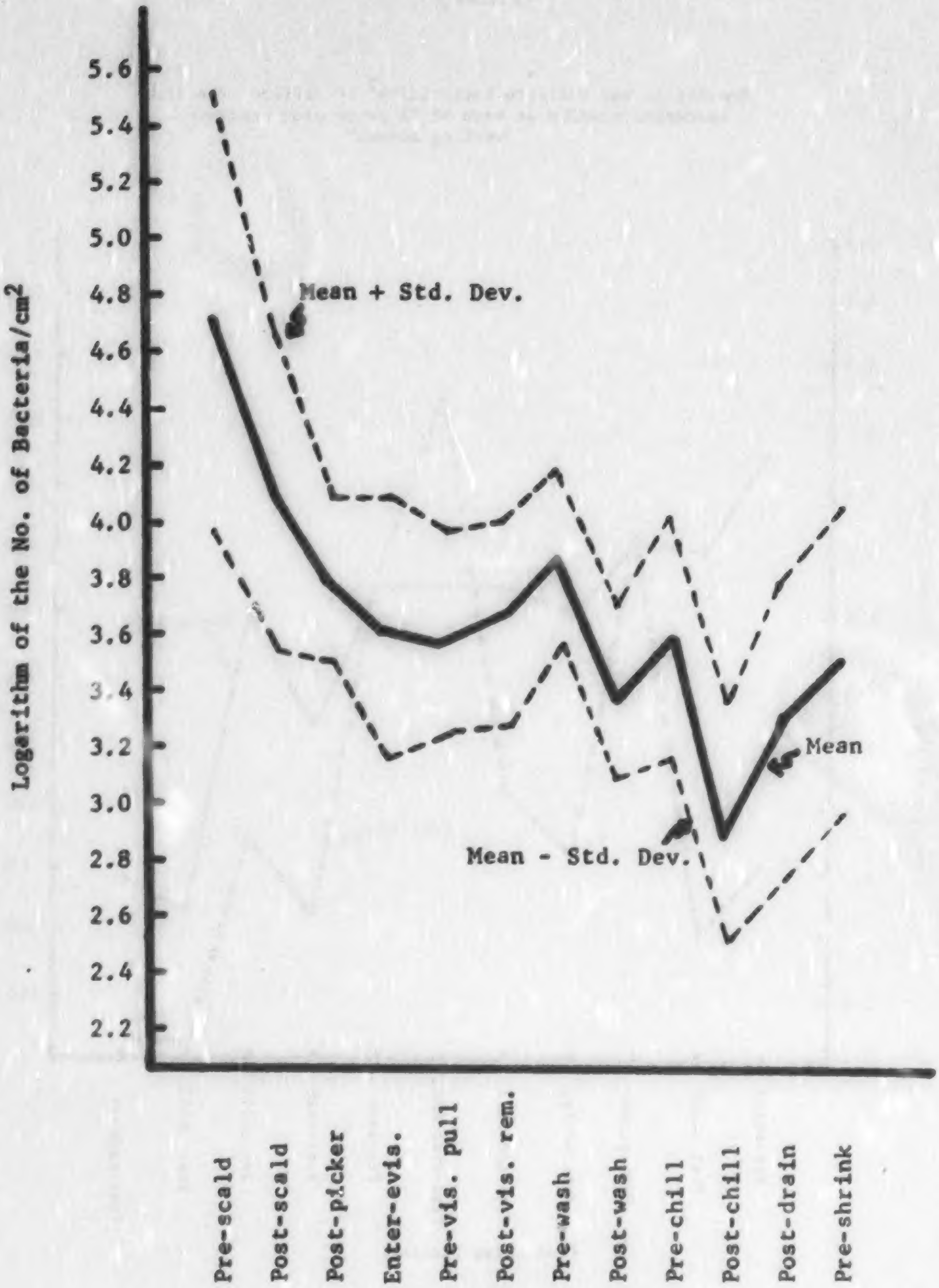


Figure 4

Number of Coliform/cm^2 of surface area from turkey carcasses sampled at 12 processing stations

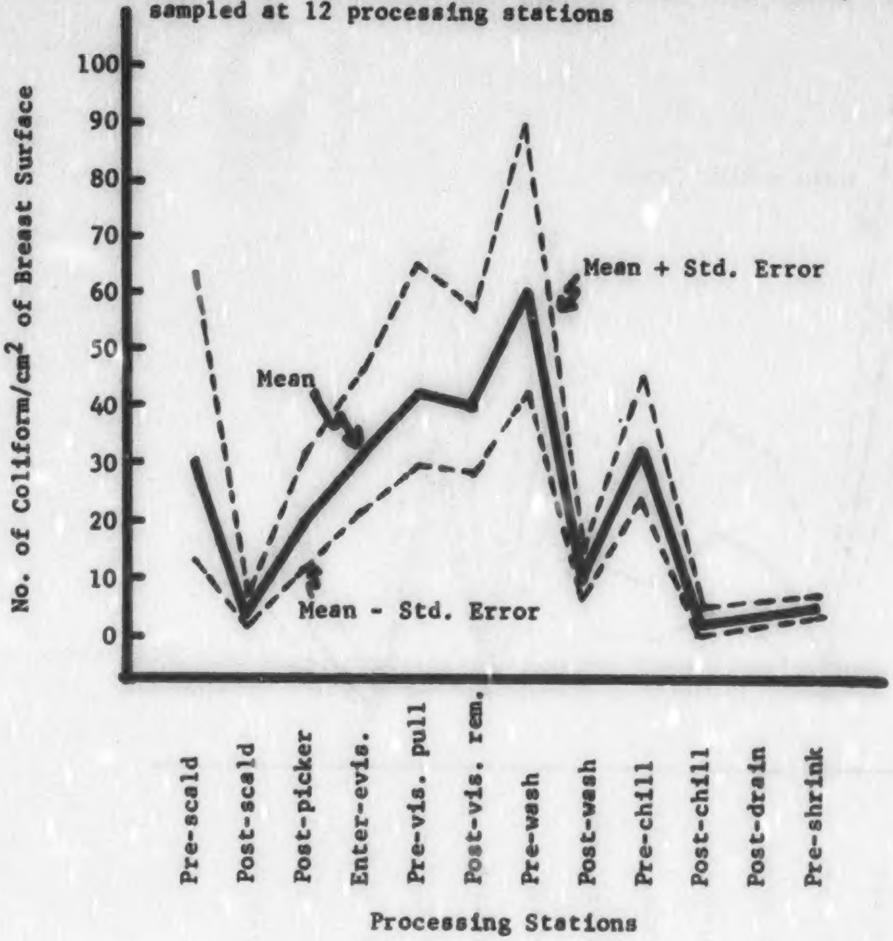
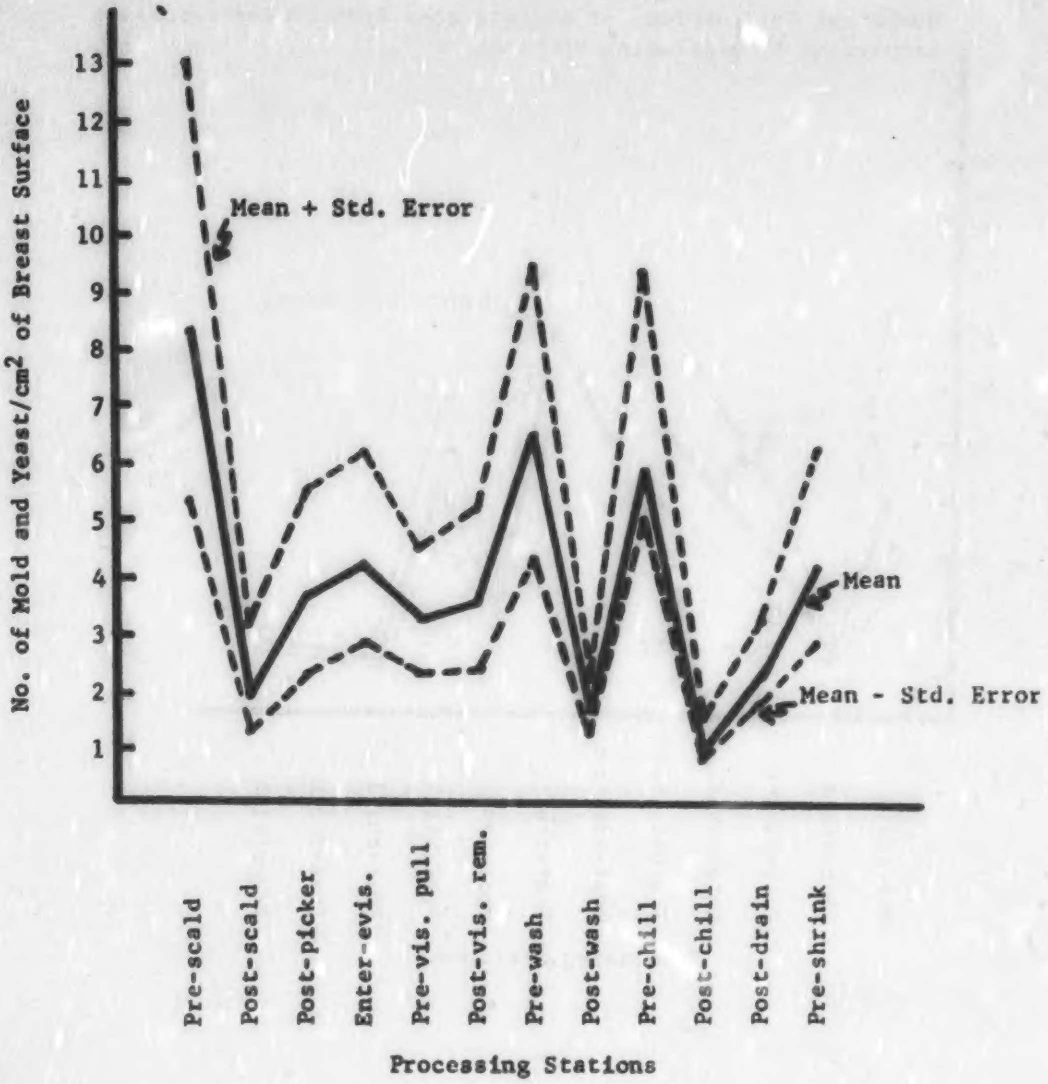


Figure 5

Mold and Yeast obtained from turkey carcasses sampled at 12 processing stations



and in which no water is permitted, generally result in increases in the concentrations of mold and yeast on the breast surface. Generally, prescald sample analyses indicated that mold and yeast are present in about equal numbers. The scalding operation effectively reduced the relative concentration of mold so that during the latter stages of processing, yeast constituted about 90-95% of the saprophytic population. It should also be noted that the handling and carcass transport required for draining and bagging produces a small but significant increase in concentration of mold and yeast.

Salmonella on the final turkey product was detected at very minor concentrations--generally about two Salmonella per 1000 cm^2 of surface area (Figure 6). The washing action of the scalding and the picker operations effectively reduced carcass Salmonella concentration. Only minor changes in Salmonella numbers were noted during the eviscerating and packing operations.

Calculations to characterize the extent of bacterial reductions which can be associated with specific processing functions indicate a reduction of 95% of the initial mesophilic organisms is obtained during the overall processing operation (Table 10 and 11). Almost identical results were obtained in both the broiler processing and the turkey processing studies. However, differences were noted in the bacterial reductions associated with the dressing and eviscerating operations of broilers and turkeys. A significantly greater percentage of bacterial reduction was obtained in the turkey dressing operation than in the broiler dressing operation. This difference can probably be attributed to the much smoother breast skin on the turkey carcass than on the broiler carcass. This difference in skin texture would make it much more difficult to remove organisms from the broiler carcass. However, a significantly greater bacterial reduction was associated with the evisceration of broilers than with the evisceration of turkeys. The extra carcass handling of turkeys for the draining and bagging operations resulted in a relatively large increase in carcass mesophiles. This post-chill handling effect was not noted in processing broilers since the post-chill operations in broiler processing are, to a large extent, automated.

Characterization of the bacterial reduction properties of scalding, washing and chilling operations, indicate that these three processing functions contribute significantly to the reduction of bacterial numbers during processing (Table 12 and 13). When the broiler and turkey data are combined reductions of 67%, 63% and 85% in surface bacterial numbers can be attributed to the scalding, washing and chilling operations respectively (Table 10). It is interesting to note that in poultry processing, bacterial reductions are obtained only from those operations in which water is in continuous use.

Chemical analysis of the water effluent from several broiler processing areas indicate that water discharge from the scalding, washing and chilling operations are not necessarily the major contributors to the final plant effluent content of either BOD or COD (Table 15). Chill tank water effluent

Figure 6

Salmonella obtained from turkey carcasses sampled at 12 processing stations

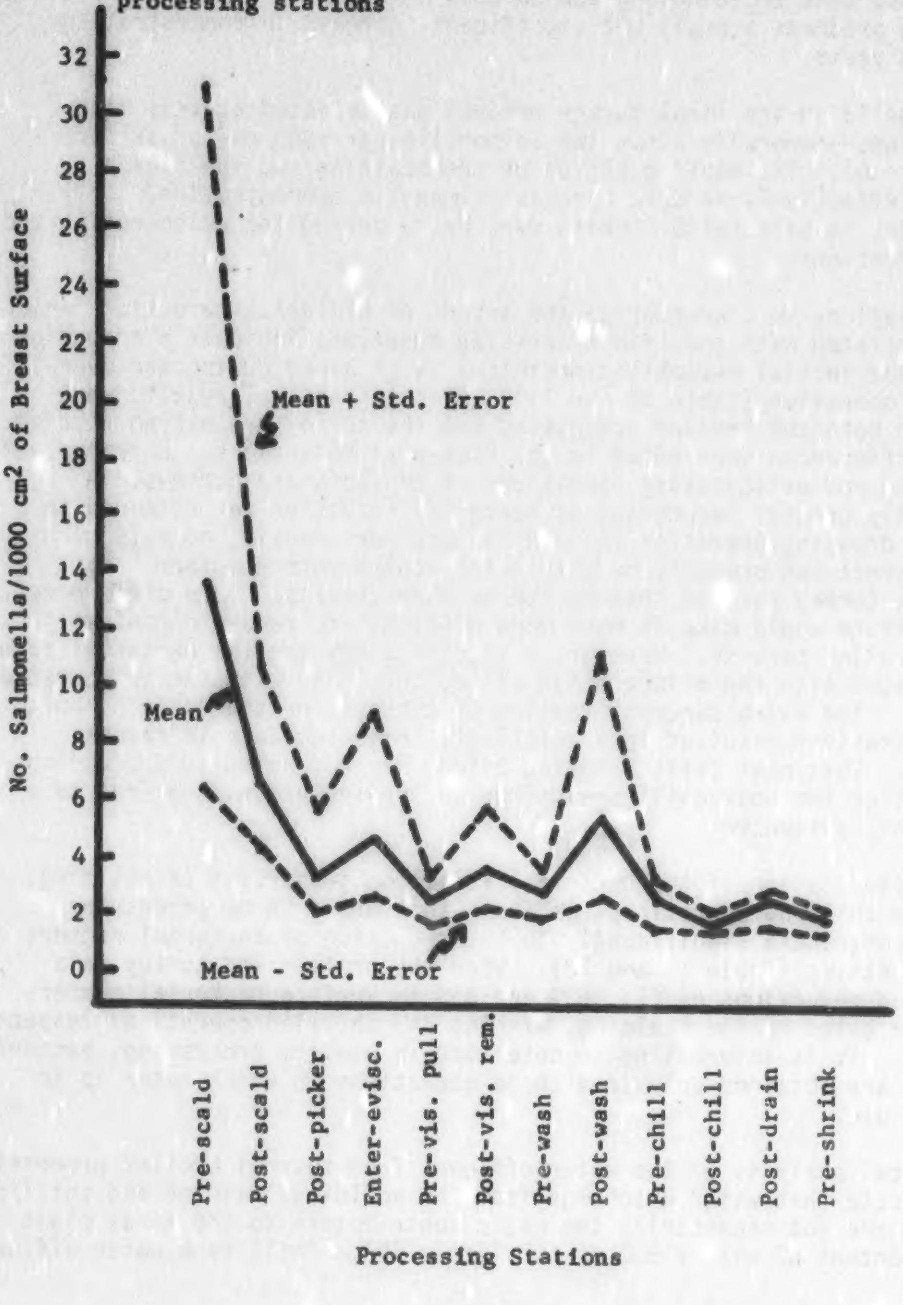


TABLE 10. PROCESSING EFFECTS ON THE BACTERIAL CONTENT OF BROILER CARCASSES*

Operation	Pre-Treatment	Post-Treatment	% Change
Dressing	32,400	10,500	-67.6
Eviscerating	10,500	1,550	-85.2
Overall	32,400	1,550	-95.2

*Number of mesophilic bacteria per cm^2 of breast surface

TABLE 11. PROCESSING EFFECTS ON THE BACTERIAL CONTENT OF TURKEY CARCASSES*

Operation	Pre-Treatment	Post-Treatment	% Change
Dressing	54,300	4,500	-91.7
Eviscerating	4,500	3,240	-28.0
Overall	54,300	3,240	-94.0

*Number of mesophilic bacteria per cm^2 of breast surface

TABLE 12. THE EFFECT OF SCALDING, WASHING AND CHILLING ON THE BACTERIAL CONTENT OF BROILER CARCASSES*

Operation	Pre-Treatment	Post-Treatment	% Change
Scalding	32,400	15,900	-5.19
Washing	12,300	4,790	-61.1
Chilling	11,800	1,230	-89.6

*Number of mesophilic organisms per cm^2 of breast surface

TABLE 13. THE EFFECT OF SCALDING, WASHING AND CHILLING ON THE BACTERIAL CONTENT OF TURKEY CARCASSES*

	Pre-Treatment	Post-Treatment	% Change
Scalding	54,300	12,100	-77.7
Washing	7,130	2,450	-65.6
Chilling	3,940	847	-79.5

*Number of mesophilic organisms per cm^2 of breast surface

TABLE 14. THE EFFECT OF SCALDING, WASHING AND CHILLING ON THE BACTERIAL CONTENT OF POULTRY CARCASSES* (BROILER AND TURKEY DATA COMBINED)

	Pre-Treatment	Post-Treatment	% Change
Scalding	41,900	13,900	-66.8
Washing	9,360	3,430	-63.3
Chilling	6,800	1,020	-85.0

*Geometric mean of the number of mesophilic organisms per cm^2 of breast surface

TABLE 15. COMPOSITION OF SELECTED EFFLUENTS FROM BROILER PROCESSING

Sample No.	Description	BOD (mg/lit)	COD (mg/lit)	Total Suspended Solids
1	1:32 PM Inline Birdwasher Drain	206	1557	425
2	1:35 PM Chill Tank #1	128	580	374
3	1:37 PM Chill Tank #2	258	995	256
4	1:40 PM Picker Drain	644	2843	296
5	1:50 PM Bird Washer #1 Picking Room	94	435	108
6	7:30 AM Scald Tank H_2O	119	384	---*
7	1:40 PM Scald Tank Overflow	321	1818	1003
8	6:55 AM Combined H_2O-Post-Settling	225	557	111
9	2:30 PM Combined H_2O-Post-Settling	446	1474	---
10	9:14 PM Combined H_2O-Post-Settling	239	731	---

*Not determined

contained about 250, inline birdwasher drain about 200 and the scald water overflow about 325 mg BOD per liter. Final plant effluent contained approximately 450 mg BOD per liter indicating another major contributor to effluent BOD. Our studies indicate that giblet and neck chill water and the process water are potentially significant contributors to final plant effluent BOD.

CONCLUSIONS

1. The scalding, washing and chilling operations are the most effective processing functions as measured by overall reduction in surface microbiological concentrations.
2. Scalding and chilling continue to be effective carcass surface cleaning systems even though bacterial concentrations in each system may increase substantially during processing.
3. Water use in poultry processing appears to be the only effective means presently being used to reduce carcass surface bacterial concentration.
4. The scalding operation effectively reduces the number of Salmonella on poultry carcasses.
5. A 95% reduction in bacterial numbers on the poultry carcass is effected by current methods of processing poultry.
6. Scalding reduces bacterial numbers by 67%, washing reduces bacterial numbers by 63% and liquid chilling reduces bacterial numbers by 85%.
7. Scalding, washing and chilling effluents are not the major contributors to total plant effluent BOD.
8. The results of these studies indicate that changes in equipment design and in methodology which may result from regulation and/or pollution concerns for less water use should also be thoroughly characterized with respect to their effects on the microbiological properties of poultry products.

TREATMENT OF PACKINGHOUSE WASTEWATER BY SAND FILTRATION

by

Dr. M. L. Rowe*

INTRODUCTION

The technology to be used for the purpose of meeting wastewater discharge requirements is an item of concern to the managers of processing plants for red meat and poultry. Previous papers by Mr. Jack Witherow and Dr. Anthony Tarquin have devoted attention to some methods of treatment available to the meat and poultry industry. However, there is a need for a variety of proven treatment methods which can be reveiwed by the plant manager, as each plant manager must consider cost, volume and concentration of wastewater, land requirements, climatic conditions, etc. in order that the best available method can be selected for each individual plant.

Funds for the planning, construction and evaluation of this intermittent sand filter project were provided by Environmental Protection Agency Grant Number 803766 and the facilities of the W. E. Reeves Packing Company in Ada, Oklahoma were used for the demonstration site. The intermittent sand filter treatment facility discussed in this report is in the early stages of investigation and is not intended to be used as design criteria until further evaluation shows that it can be a successful and feasible method of treating packinghouse wastewaters. A final report will be prepared and distributed upon completion of the research project.

HISTORY OF SAND FILTRATION

The use of sand filtration for the treatment of water and wastewater is not a recent innovation in the United States. A survey of the literature reveals the existence of sand filtration for the improvement of drinking water supplies in the United States as early as 1828 (1). Much of its use and further development immediately following the introduction of the sand filter took place in Europe.

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*Director, School of Environmental Science, East Central Oklahoma State University, Ada, Oklahoma.

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However, the accelerated growth rate in the United States, especially the eastern United States, created a demand for larger volumes of drinking water and around the turn of the century, a number of slow sand filter units were in use in the United States for the treatment of drinking water supplies.

Just as the accelerated growth rate in the United States had created a demand for methods of treating larger volumes of drinking water, the need arose for methods of treating the increasing volumes of wastewater produced by the municipalities. An experimental intermittent sand filter unit for the treatment of domestic wastewater was built in Lawrence, Massachusetts in 1888 (2). The operation of the intermittent sand filter unit proved successful. However, a rapid increase in the number of sand filter units for the treatment of sewage was not experienced in the United States until the 1940's. The limiting factors for the increased usage of intermittent sand filter units were apparently the availability of natural sand sources meeting the desired specifications and the requirement of large tracts of land.

Following World War II, the rapidly increasing number of subdivisions, mobile home parks, and resort areas in Florida created a need for economical and practical treatment systems which would produce an effluent of suitable quality. This need for simple and economical sewage treatment units for small volumes of wastewater led investigators at the University of Florida to test various designs for intermittent sand filter units (2). Much of the present knowledge concerning intermittent sand filters has come from these early studies at the University of Florida.

The early designs of intermittent sand filters have seen very little change over the years that they have been in use. The units usually consist of an underdrain bed of tile and gravel which is covered with a filter media of sand. Designs are usually determined by sand specifications, volume of wastewater, and the nature of the wastewater to be filtered. In the design of an intermittent sand filter unit, emphasis must be placed on sand specifications and suspended solids concentration of the influent. These factors must be considered in order to design a filter unit capable of experiencing a feasible period of operation before clogging of the filter media occurs.

In the past few years, workers have demonstrated the effectiveness of intermittent sand filters in reducing the suspended solids values of domestic waste which has received prior treatment in lagoon systems. Evidence of the effectiveness of intermittent sand filters for the reduction of suspended solids can be found in the published works of Reynolds (3), Marshall (4), and Walter (5). Other supportive evidence for intermittent sand filters as a means of lowering suspended solids values can be found in reports by Grantham (6) and Furman (7).

PILOT SCALE OPERATION

A review of the work by the authors cited above led Witherow and Rowe to consider the use of intermittent sand filters as a means of polishing the wastewaters from the lagoons at the W. E. Reeves Packing Company in Ada, Oklahoma. Other investigations were being conducted at the treatment facilities of the Reeves' plant at that time and the site served as a suitable place for the operation of two pilot scale intermittent sand filter units.

Two pilot scale units were constructed in close proximity to the lagoon system at the Reeves' facility. Each unit was formed by welding two 55-gallon barrels end-to-end. Effluent lines were installed in the bottom of the units and each unit was filled with gravel and sand to serve as the filter media.

The pilot scale filter units contained 18 inches of gravel, ranging from 0.25 to 1.25 inches in diameter, with the larger gravel particles in the bottom of the unit. The gravel was then covered with 36 inches of sand which has an effective diameter of 0.2 millimeters (mm). Investigations were then conducted by applying wastewater from the extended aeration lagoon and the secondary stage lagoon to the filter units at a rate equivalent to 0.5 million gallons per acre per day (mgad).

Analysis of the influent and effluent samples collected during the pilot scale study revealed a 5-day Biochemical Oxygen Demand (BOD_5) removal of approximately 70 per cent and a suspended solids reduction of approximately 50 per cent. The concentrations of BOD_5 and suspended solids in the effluent from the pilot units were converted to lbs/1000 lbs of Live Weight Kill (LWK) and compared to the Best Practical Treatment (BPT) and Best Available Treatment (BAT) guidelines for small meat processing plants. The results showed that the effluent from the filter units could meet the suspended solids limits for BPT and BAT guidelines. All BOD_5 samples from the pilot units were below the BPT values and only one was slightly in excess of the BAT guidelines. The results of the pilot scale study led to the development of the large scale project which is currently being conducted at the W. E. Reeves' facilities.

PRELIMINARY DESIGN

Since the treatment facilities at the W. E. Reeves' plant had been used for previous investigations by Mr. Jack Witherow and the author, information pertaining to the daily volume of wastewater from the plant and the concentration of various pollutants in the wastewater was readily available to the investigator. The investigator also had access to information pertaining to the average suspended solids concentration and average BOD_5 values of the effluent from the extended aeration lagoon and the secondary stage lagoon in use at the treatment facilities. Other information pertaining to sand and gravel specifications, recommended loading rates onto the filters, filter design, etc. were available from the literature and the pilot study previously conducted by the investigator. All of this information was used by the investigator in developing the preliminary design of the project which is now in progress.

The preliminary design for the filter project was based on an average wastewater flow of 18,000 gallons per day with a maximum daily flow of 30,000 gallons, as these volumes were known to be characteristic of the flow from the W. E. Reeves' plant. During the development of a preliminary design, a site adjacent to the existing lagoon system was selected for the proposed sand filter units so that loading from either the extended aeration lagoon or the secondary stage lagoon would be possible by gravity flow. The proposed site for the sand filter units also had the advantage of providing a means of diverting the flow from the filters to the existing lagoons in case of an accidental spill or necessary filter repairs.

During the planning of the project, it was decided that instead of one filter unit, two small units of unequal size should be constructed. This would offer the advantage of having two different surface areas for the purpose of investigating different hydraulic loadings and would have the added advantage of providing one operable filter to be used while the second was being cleaned.

A grant proposal containing the results of the pilot investigations conducted by the investigator and the proposed preliminary designs were submitted to the Environmental Protection Agency for review. The review of the proposed project was favorable and the project was funded. After the approval of the grant proposal, the development of a detailed design which consisted of drawings, survey reports, and material specifications was completed.

CONSTRUCTION

The final plans called for the construction of two filter units. The filter units were to be formed by clay embankments on three sides, and the fourth side of each filter unit would be formed by a common concrete wall between the two units. The purpose of the common wall was to reduce the amount of land required for the filters. Thus, the construction would be similar to that required for the building of a lagoon. Each unit would consist of 36 inches of sand over 18 inches of gravel and each filter unit would have a separate underdrain system.

Specifications called for the bottom of the filter units to be formed of compacting six inches of clay. Plans also specified that the bottom of each filter was to be sloped toward the effluent drain to insure proper drainage from the filters. A slope of 6 per cent was recommended.

The embankments were to be constructed of clay soil and were to be built so that the interior of the dikes were sloped at a ratio of 2.5 horizontal units to 1.0 vertical units. The elevation from the bottom of each filter unit to the top of the dike was to be a minimum of 9.5 feet, thus allowing a freeboard of at least 5 feet above the surface of the sand. Specifications called for the tops of the embankments to be at least 8 feet wide so that vehicles and machinery could be used at the treatment site. Further design information is given in Figure 1.

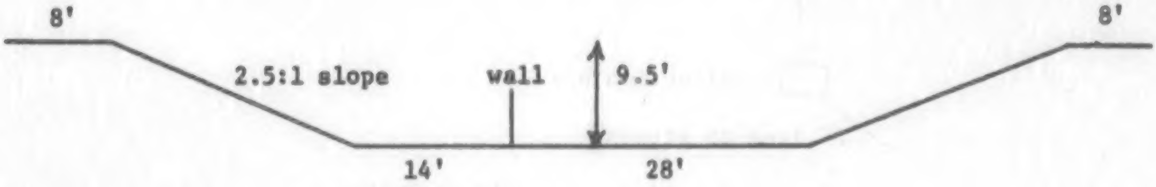

Figure 1. Cross-Section of Filter Unit

A factor which determined the dimensions of the bottom of the sand filter units was the space required for the normal operation of heavy equipment, such as a dozer, during the construction phase of the project. The final specifications for the bottom of the structure called for a width of 12 feet and a length of 42 feet. After the bottom was compacted, the 6 inch concrete wall was to be poured to form two filter units with bottom dimensions of 12 feet by 14 feet and 12 feet by 28 feet respectively.

By following the recommendations for the bottom dimensions, slope of interior dike, and depth of sand and gravel, the completed structure would consist of two filter units with sand surface areas of 880 and 1220 square feet. If an average wastewater flow of 18,000 gallons were loaded to the small sand filter, the hydraulic loading would be approximately 0.90 mgad, and if one-half of an average days flow were loaded onto the small filter, the resulting hydraulic load would be approximately 0.45 mgad. Corresponding loading rates of 0.64 and 0.32 mgad could be examined by using the larger filter.

The underdrain network of each filter was to consist of a series of 5-inch diameter perforated pipes on the bottom of the filter bed. Spacing of the pipes was to be approximately 3 feet, and each lateral line was to be connected to a 6-inch diameter pipe serving as the main drain from the filter unit. The main drain line was to project through the walls of the dike and empty into a sample collection box. Effluents from the filters would be discharged from the collection box to the stream that runs through the Reeves' property. Figure 2 shows the layout of the drain system of both filters.

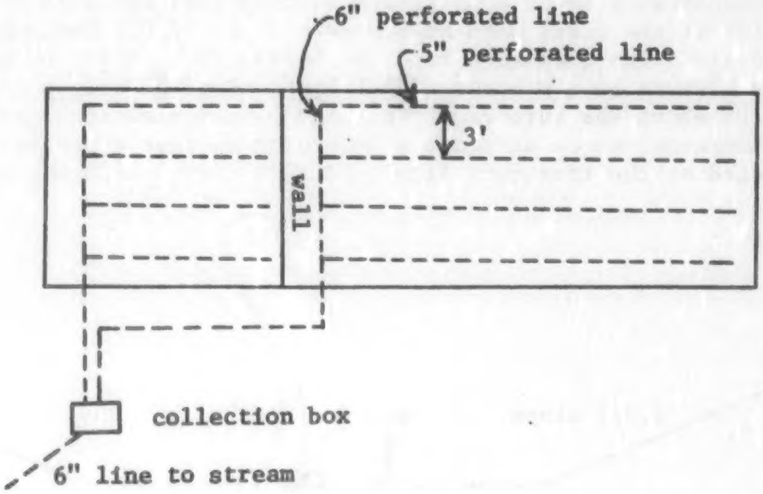

Figure 2. Underdrain System

The lateral lines of both filter units were to be covered with 18 inches of gravel with diameter size ranging from 0.5 to 1.5 inches. Specification called for the gravel to be covered with 36 inches of washed sand. Sand specifications called for a sand source having an effective diameter of 0.2 mm and a uniformity coefficient of 3. A cross-section of the filter units is presented in Figure 3.

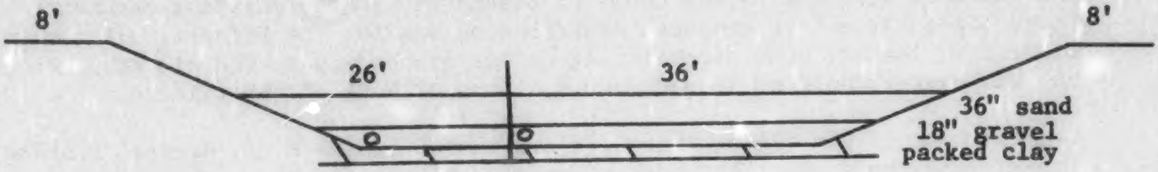
8'
8'
26'
36'
36" sand
18" gravel
packed clay

Figure 3. Cross Section

The filters were to be located so that the effluent from the extended aeration lagoon or the secondary stage lagoon could be loaded onto the filter units by gravity flow. However, the construction plans only required a system for loading the effluent from the extended aeration lagoon to the filter units. The plan was to add a system for loading the effluent from the secondary stage lagoon to the filters at a later date, only if the filter were found to be incapable of handling the wastewater from the extended aeration system. The location of the filter units is shown in Figure 4.

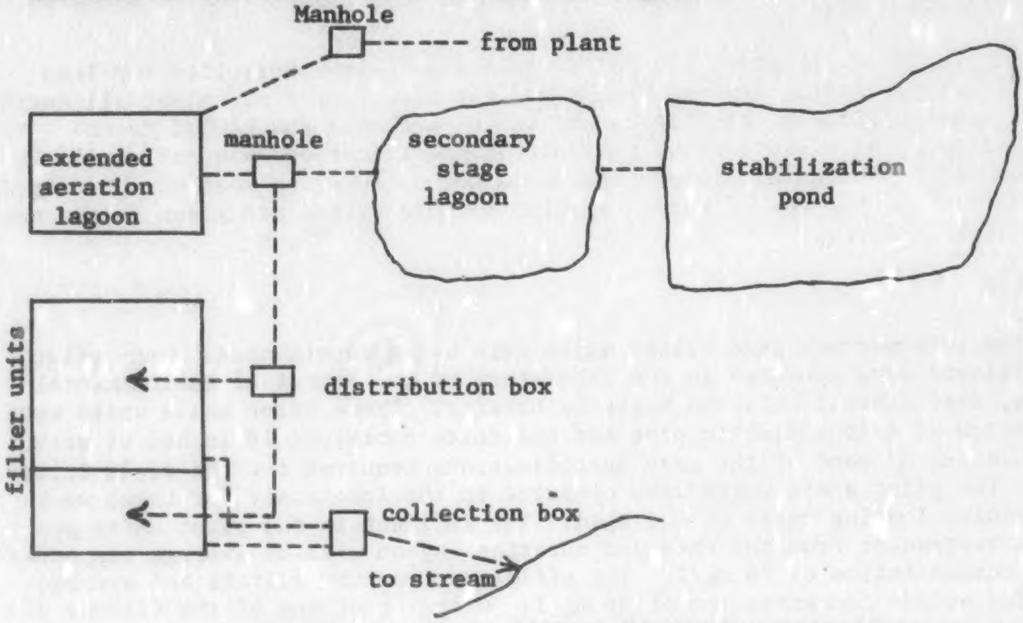
Manhole
from plant
extended aeration lagoon
manhole
secondary stage lagoon
stabilization pond
filter units
distribution box
collection box
to stream

Figure 4. W. E. Reeves' Treatment Facilities

A manhole already existed between the extended aeration lagoon and the secondary stage lagoon and the plans called for utilization of the existing manhole. The plans called for the installation of a six inch line from this manhole to a distribution box to be constructed in close proximity to the sand filters. A six inch distribution line could then be installed from the distribution box to each of the filters. By using this scheme, the wastewater from the extended aeration lagoon could be discharged to the existing secondary stage lagoon or to the proposed distribution box for the filters. If the wastewater from the extended aeration lagoon was discharged to the distribution box, the wastewater could be loaded onto only one or both of the filters.

Construction of the filter units was contracted by the W. E. Reeves' Packing Company and the project has been completed, except for the bermuda grass coverage of the dikes. Construction began in October and the project was completed in approximately 60 days. The construction time was longer than expected, due in part to unfavorable weather conditions. Also, the site which was selected for the sand filters required the removal of several feet of rock in order to reach the desired depth for the filter units. This required extensive blasting followed by time-consuming rock moving operations. A final inspection by the principal investigator revealed that the construction phase of the project had been completed and that the building specifications were met.

COST

The total contract price for the construction of the sand filter units was $12,850. This included the construction of the two filter units, the distribution system, and the effluent collection system. This price also included the cost of providing a bermuda grass cover of the dike, which has not been completed at the present time.

According to the contractor, the units could have been constructed for less money if extensive blasting operations had not been required. Also, all earth for the construction of the filters had to be purchased and hauled to the construction site, since soil of the desired specifications was not available at the construction site. These figures do not include the cost of the extended aeration system, but cost figures relating to this system are given in the report by Mr. Jack Witherow.

OPERATION

While the intermittent sand filter units were being constructed, four pilot scale filters were operated in the laboratory of the School of Environmental Science, East Central Oklahoma State University. These pilot scale units were constructed of 6 inch plastic pipe and the units contained 18 inches of gravel and 36 inches of sand of the same specifications required for the field filter units. The pilot scale units were operated in the laboratory for three weeks at hydraulic loading rates of 0.2 mgad. The influent to the pilot units was settled wastewater from the extended aeration lagoon with an average suspended solids concentration of 76 mg/l. The effluents from the filters had average suspended solids concentration of 26 mg/l. Clogging of any of the filters did not occur during the three weeks of operation.

The construction of the sand filters at the demonstration site was completed in early December, and operation of the filters was scheduled to begin at that time. However, mechanical difficulties had been experienced with the aerator in the extended aeration pond and the aerator was removed from the pond for major repairs. After the aerator was returned to the extended aeration lagoon, several weeks of aeration were required before the principal investigator felt that the wastewater in the extended aeration system was suitable for use in the sand filter investigation.

In the latter part of January, the operation of the sand filters began. At that time, electrical outlets had not been installed at the manhole between the extended aeration lagoon and the distribution box for the sand filters and therefore, an automatic sampler could not be used at the site for the collection of a composite sample. The principal investigator felt that loading the filters at this time would be beneficial to the project even though composite sampling wasn't possible at that time. The only index, therefore, to the quality of the wastewater loaded onto the filters was obtained by examining a grab sample of settled wastewater from the extended aeration lagoon.

A 7-day clock timer was used in conjunction with the aerator, so that operation of the aerator would cease at midnight. Another 7-day clock timer was used to control the hydraulic valve at the manhole between the extended aeration lagoon and the sand filters. This system was designed so that the valve would open at 2:00 a.m. and remain open until 6:00 a.m. This scheme allowed a two-hour settling period after the shut-off of the aerator and a loading time onto the filters of 4 hours. This early morning loading was selected in an attempt to reduce the length of time that the wastewater on the filters would be exposed to the sunlight.

The two filters were loaded simultaneously. It was obvious that the filters were beginning to clog after only 2 days of operation because the wastewaters added on one day was requiring more than 24 hours before filtering through the system. Therefore, the operation of the filters was stopped after only four days. By the fourth day several feet of water had accumulated on the filter surface and damage of the interior dikes due to erosion had occurred. The grab samples of settled wastewater from the extended aeration pond indicated suspended solids values of only 66 mg/l. The suspended solids concentration of the effluent from the filters were less than 20 mg/l and turbidity values of less than 10 JTU's were observed. After the loading of the filters had been stopped, a period of six days was required before the filter had drained and was dry enough to clean.

An examination of the filters after the surfaces were dry revealed an accumulation of slude approximately 0.5 inches thick. The sludge layer was removed and the sand surfaces were cleaned and raked. Visual examination indicated that the sludge had not penetrated the sand more than two inches. The small number of days of operation before clogging of the filters and the long drying time indicated that the suspended solids concentration loaded to the filter must have been much greater than the analyses of the settled lagoon sampler indicated. This belief was strengthened by examining the pilot study data.

It was learned that sludge had not been wasted from the extended aeration system for several months. This led the investigator to believe that the sludge concentration in the extended aeration lagoon was too high and that settling was not occurring properly. The theory was proposed that the suspended solids concentration in the effluent from the pond was increasing as the effluent was discharged from the lagoon. Therefore, 16,000 gallons of sludge were removed from the pond and applied to the fields of the W. E. Reeves' Company. It was hoped that the settling of the solids in the extended aeration pond would be improved by the reduction of the sludge.

After the 16,000 gallons of sludge had been removed, two weeks of aeration of the lagoon were allowed before placing the filters in operation again. Then in mid February, loading of only the small filter was begun. The same settling and loading times as those used in the first investigation were used during this phase of the study. The small filter was clogged after two days of operation. Loading was then begun on the large filter. This filter appeared to be clogged after four days of operation. The sludge accumulation to the sand surfaces during this phase was similar to that experienced in the first attempt at using the filters.

During this phase of the investigation, composite samples were collected at the manhole between the extended aeration lagoon and the filters. The samples were composited during the four hours that the filters were loaded. Analysis of these samples revealed suspended solids concentration of more than 200 mg/l. These values were much higher than had been expected and were also higher than those seen at this same sample point during previous investigations conducted at the Reeves' site.

These results led the investigator to re-examine all components of the electrical system controlling the aerator and the hydraulic valve. This investigation revealed that malfunctions had occurred with the timing system and that the aerator had been in operation part of the time during the four hour loading period, thus agitating the sludge and increasing the amount of sludge loaded onto the filters.

These malfunctions were corrected and it was decided that a longer settling period in the pond would be advantageous. Loading of the filters resumed on March 23, 1976, and the filter units appear to be functioning in a satisfactory manner.

The timer system for the aerator has been adjusted to shut off the aerator at 11:00 p.m. and to remain off until 9:30 a.m. on the following morning. The timer for the hydraulic valve was changed to open the valve at 5:00 a.m. and close at 9:00 a.m. This schedule allows a settling time of 6 hours and insures that the aerator does not resume operation until after loading of the filters has been completed.

Composite samples taken at the manhole between the extended aeration lagoon and the filter indicate that the influents to the filters have contained average suspended solids concentration and BOD5 values of 65 and 37 respectively.

Effluents from the large filter have shown average BOD_5 and suspended solids values of 8 and 13 mg/l. The average BOD_5 and suspended solids values of the effluents from the small filter have been 8 and 12 mg/l respectively. These values represent a 5-day period of operation for each filter.

A visual examination of the sand surface after this short period of operation of both filters has shown very little accumulation of sludge. Also, the period of time required for all the wastewater applied to the surface beds has been small. All wastewater has been dissipated from the sand surface in less than 3 hours after the last wastewater is applied to the filters.

SUMMARY AND CONCLUSIONS

An intermittent sand filter for the treatment of packinghouse wastewater is being evaluated at W. E. Reeves' Packing Plant in Ada, Oklahoma. The wastewater from the plant is treated in an extended aeration lagoon, settled, and then discharged to an intermittent sand filtration unit. A number of difficulties have been encountered with the demonstration project, but current operation appears to be successful. Average BOD_5 and suspended solids concentrations in the effluents from the filter units have been 8 and 12 respectively.

Although performance of the filter appears to be acceptable, the study is still in the early stage of investigation and a much longer study period is required before definite conclusions can be made. The project plan will require the operation of the filter unit through warm and cold weather conditions with a comprehensive analysis of raw wastewater from the plant, the effluent from the extended aeration lagoon, and the effluent from the sand filter.

Various hydraulic loading rates will be examined and the length of filter-run before clogging will be determined. The ability of the filter system to meet effluent guidelines will be determined after the study is completed. Upon the completion of the study, a final report relating to construction, cost, and operation will be prepared.

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WASTE TREATMENT FOR SMALL MEAT AND POULTRY PLANTS

by

Jack L. Witherow*

INTRODUCTION

The technology herein is presented to help meet the wastewater treatment requirements of small plants slaughtering and processing cattle or chickens. For the convenience of plant managers, abbreviations of scientific terms are defined in the text and in the appendix.

Solving a wastewater problem can best be undertaken in several interrelated but distinctly separate steps. These are preliminary design, funding, detailed design, construction, and operation. Each step will involve different technologies, different individuals, different decisions, and result in different outputs. None of the steps can be skipped, since the results of one are the basis for the next. Actually, these five steps simplify a long but necessary procedure to solve a problem at minimum cost. By grouping those tasks which lead to a recognizable and defined output, the chances of a costly mistake or omission are reduced.

PRELIMINARY DESIGN

The preliminary design is the most important of the five steps in solving the problem and minimizing cost. The output of the preliminary design is the selection of the in-plant controls, the treatment processes, and the site. These are obviously major decisions and a number of physical facts must be gathered and requirements satisfied prior to making these selections. Not only must these selections be based on physical and regulatory constraints, but also on cost. Minimizing cost is the major function of preliminary design.

Discharge Regulations

The wastewater discharge limitations are the obvious initiation point. Governmental regulatory groups will be involved. If the plant's discharge goes into a sewer, the municipal government will have restrictions and sewer charges. Meeting their requirements will be considerably different than meeting discharge requirements by the state or federal government under a National Pollutant Discharge Elimination System (NPDES) permit. However, the treatment processes described herein can apply to either discharge situation.

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* Food and Wood Products Branch, Corvallis Field Station, Industrial Environmental Research Laboratory-Cincinnati, U.S. Environmental Protection Agency

Municipal restrictions, that are of concern to meat and poultry plants, usually involve oil and grease concentration, feathers, viscera, paunch manure, bone, hair, hides and fleshings. These restrictions are to prevent obstruction in the sewer system or treatment plant. Most small processors meet these restrictions by in-plant control and pretreatment with screens and grease traps.

All but a few municipalities do, or will, have sewer charges based on flow and concentration of pollutants. The charges for flow may be reduced if the wastewater discharge is delayed to reach the treatment plant during the night. Pretreatment can reduce the concentration and thereby the sewer charge. The installation of an anaerobic or aerated lagoon with a controlled discharge may pay a high return in terms of reduced sewer charges.

Plants that discharge to surface water are required to meet the limitations in their NPDES permit. Limitations in these permits are in pounds per day for 5-day Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids (TSS). Other limits are pH not less than 6.0 and not greater than 9.0 standard units and fecal coliforms equal to or less than 400 most probable number per 100 milliliter (mpn/100 ml). Ammonia (NH_3^-) and fats, oils or greases (FOG) discharges are restricted in either lbs/day or milligrams per liter (mg/l).

The two bases for discharge limitations are receiving water quality and available technology. Water quality limitations are used where the discharge would be more restricted than with technology limits, but only where necessary to protect the established uses of the watercourse. Discharge limitations based on water quality vary depending on location of the plant. Technology limitations are based on National Effluent Guidelines and vary with plant size measured in terms of live weight killed (LWK). The National Effluent Guidelines have limitations to be met by July 1, 1977, limitation for new sources of discharge, and more strict limitations to be met by July 1, 1983. These limitations are further categorized by types of plants within the meat and poultry industries. Table 1 shows the limitations that would apply to almost all small plants. These limits are averages of daily values within 30 consecutive days. Maximum limits for any one day are twice those shown in Table 1. The 1977 limitations are based on Best Practical Control Technology currently available (BPT) and the 1983 limitations are based on Best Available Technology economically achievable (BAT).

There is also a 1983 ammonia as nitrogen (NH_3-N) limitation of 4.0 mg/l for 30-day average value and 8.0 mg/l maximum for any one day. A recent court decision has declared that these limitations are insufficiently supported and a new study to establish an ammonia limit is underway. Future national limitations on ammonia will likely require treatment processes that discharge low concentrations of ammonia. Several States require discharges to have 2.0 mg/l or less of NH_3-N. In preliminary design, the treatment system should be planned to incorporate processes by 1983 which discharge a low level of ammonia.

The effluent limitations shown in Table 1 for poultry and fowl processors were proposed on April 24, 1975. Final guidelines have not been published but are expected in the near future.

Table 1. National Effluent Guidelines
(lbs/1000 lbs LWK)

Parameters	Slaughter-houses	Packing-houses	Chicken Processor	Fowl Processor
1977 Limitations (BPT)				
BOD_5	.12	.17	.46	.61
TSS	.20	.24	.62	.72
FOG	.12	.08	.20	.15
New Source Limitations (include the above plus NH_3-N)				
NH_3-N	.17	.24	.20	.15
1983 Limitations (BAT)				
BOD_5	.03	.04	.30	.23
TSS	.05	.06	.34	.27
FOG	10*	10*	.20	.07

*Value for both maximum day and 30-day average in mg/l.

Monitoring Regulations

NPDES permits and some municipalities have monitoring requirements. Measurements are required of the physical, chemical, and sometimes the biological characteristics of the waste discharged. These measurements can cost as much as $100 for each sample depending on the number of analyses required. The frequency of sample collections and the number of analyses required should be reviewed as carefully as the discharge limitations.

Municipalities often base their sewer charge on flow, BOD_5, TSS, and FOG. To calculate the charge, measurements on these parameters are usually made prior to each billing. Municipalities frequently have the measurements made by their personnel, but plant managers often have the results verified if unusually high charges are levied. Flow can be checked by water meter readings, or a wastewater flume and gauge can be installed. If a portion of the sample collected by the city is sent to a commercial laboratory for verification of BOD_5, TSS, and FOG, a charge of about $50 can be expected. The charge for sample collection, preservation, and transportation will be in proportion to the manhours required and the shipping distance. Laboratories can be expected to report up to 20 percent difference in concentration. The usual cause of increased concentrations of these pollutants is unnecessary material losses when the sample was collected.

The requirements for monitoring on the NPDES permits vary depending on where the permit was issued. The permit group at EPA's headquarters has recommended that for small plants, BOD_5, TSS, Fecal Coliforms, and flow be monitored once a month and that oil and grease, orthophosphate, ammonia, pH and temperature be measured twice a year for small plants with discharges under 50,000 gallons per day (gal/day) and quarterly for plants with flows between 50,000 and 1,000,000 gal/day.

Two economical means of meeting these monitoring requirements are: (1) Plant personnel would collect, ice and ship the samples to a commercial laboratory for analysis; they would take measurement of flow, temperature and pH and then prepare, file and mail the reports. (2) An employee would be trained to do the chemical analyses and fulfill all the monitoring requirements. The first option is generally the most economical when monthly monitoring is required with expenditures per discharge point of about $1,000 per year.

Where weekly monitoring of these parameters is required annual expenditures will be about $5,000 per year for option one; and most managers will select option two. With option two, there would be costs for analytical equipment, supplies, and laboratory space, but the major cost would be manpower. Analytical equipment costs would be about $2,000, but an employee would need to devote part of two days per week to monitor the discharge. Option two offers the advantages of having better control over the waste treatment system and also provides analytical facilities to run quality control on the meat products.

The guidelines or regulations used to establish and enforce discharge limitations, sewer charges, and monitoring requirements are interpreted by regulatory personnel. All of these items should be thoroughly discussed with these people to prevent any misunderstandings or unnecessary requirements. Only after a plant manager fully understands the discharge restrictions, monitoring techniques, and the relationship of costs, can he begin to select the most economical means of waste treatment and control.

In-Plant Waste Reduction

Control of in-plant wastes is heralded by industry as the most cost effective means of reducing a wastewater problem. The saving of material previously lost to the sewer has two economic benefits: (1) It can be sold as product or as a by-product, and (2) it reduces the cost of wastewater treatment. In-plant waste reduction involves changes in water usage, process equipment, and process operation and may require new equipment to collect, transport or process the material saved. These items are associated with capital expenditures so evaluation of the potential savings is necessary.

A determination of the potential for in-plant control should be made in conjunction with a survey of the wastewater to be treated. Both the volume of flow and concentration of pollutants can be compared with average and minimum discharge conditions in the industry. This comparison will indicate the potential for reduction in material losses and treatment costs. For small plants only limited chemical analyses are practical, but flow measurements and accompanying reduction in flow can be easily undertaken. Thus water usage is of special value to these plants and is given in Table 2.

Table 2. Typical Wastewater Characteristics
(per 1000 lbs LWK)

Parameters	Slaughter-houses	Packing-houses	Chicken Processors	Fowl Processors
Flow Ave.	640	940	9.3*	12.9*
(gal)-Min.	160	240	4.2*	2.9*
BOD_5 Ave.	6.0	8.1	9.9	15.2
(lbs)-Min.	1.5	2.3	3.3	11.8
TSS Ave.	5.6	5.9	6.9	10.1
(lbs)-Min.	0.6	0.6	0.1	6.1
FOG Ave.	2.1	3.0	4.2	2.3
(lbs)-Min.	0.2	0.8	0.2	0.7

*gal/bird with chickens @3.4 lbs & fowls @5.1 lbs.

Treatment costs are proportional to both flow volume and quantity of pollutants (e.g. BOD_5, TSS, and FOG). The costs attributed to flow are between 50 and 80 percent of the total cost. A reduction in water use will reduce the quantity of pollutants. Excess water use removes body fluids and tissue from the product and floor scraps thus increasing the amount of pollutants. Therefore, a reduction of water usage should be stressed. The use of automatic closing valves, pressure regulators, quick open and close valves, and nozzles are simple means of reducing water use. Clean water, i.e. air conditioning water, steam condensate, jacket-cooling water, should be segregated from wastewaters. Reuse of these waters can reduce the wastewater volume needing treatment. There are several operations where USDA accepts nonpotable water use, e.g., as in feather-flow-away flumes or rendering condensers.

Next to reducing overall water volume, reducing unnecessary water contact with the product, by-products, and waste materials should be stressed. Typically this encompasses such things as the use of nozzles to more effectively use the water to wash the product, the transporting of by-products without a water carriage, and the dry clean-up and disposal of scraps prior to washing the equipment and floors.

Blood is the major pollutant in wastewater from poultry and meat slaughtering plants, and where it enters the sewer can be easily detected by color. The use of containers and collection troughs have been demonstrated effective in keeping the blood out of the sewer from the bleeding operation and from those cutting operations which release large quantities of blood. In beef slaughtering plants, dry collection and transportation of the paunch contents can reduce the waste load by some 20 percent. A dry clean-up of the poultry receiving area or the cattle holding pens prior to washing can reduce the waste load significantly. Land disposal of these segregated wastes is common for small plants. The general concept in reducing the quantity of pollutants is to keep waste material off the floor and out of the sewer.

In-plant waste reductions that are built into the equipment usually remain effective; those that require more labor, such as turning off washing sprays during breaks and lunch periods, often slip unless direct responsibility is assigned to an individual.

There are a number of reports describing technology that was successful in reduction of waste discharges from meat and poultry plants. For the manager who needs to fully explore in-plant control opportunities, reports available from EPA or NTIS, 5285 Port Royal Rd., Springfield, VA 22151, are:

"Water and Waste Management in Poultry Processing," Roy E. Carawan, William M. Crosswhite, John A. Macon, & Byron K. Hawkins, Environmental Protection Technology Series, EPA 660/2-74-031, May 1974.

"Characterization and In-Plant Reduction of Wastewaters from Hog Slaughtering Operations," Paul M. Berthouex, Donald O. Dencker, David L. Grothman, & Lawrence J. P. Scully, Proceedings of Seventh National Symposium on Food Processing Wastes, EPA, April 1976.

"Workshop on In-Plant Waste Reduction in the Meat Industry," Jack L. Witherow and James F. Scaief, Environmental Protection Technology Series, EPA (In Review).

"In-Process Pollution Abatement-Upgrading Poultry Processing Facilities to Reduce Pollution," EPA Technology Transfer Seminar Publication, July 1973.

"In-Process Modifications and Pretreatment-Upgrading Meatpacking Facilities to Reduce Pollution," EPA Technology Transfer Seminar Publication, October 1973.

"In-Plant Waste Control," W. H. Miedaner. The National Provisioner, Vol. 167, No. 8. August 19, 1972. pp. 22-28.

Wastewater Characterization

Characterization of the waste flow is necessary to select the treatment process, to size these processes, and to estimate cost. Treatment plant design for new processing plants must be based on intended production and industry wide wastewater characteristics as shown in Table 2. However, the four fold increase between minimum and average conditions shown in Table 2 clearly shows the advantage of a wastewater survey prior to design. Expenditures can be several times that required without an accurate wastewater survey.

The variations of flow volume and waste concentration from hour to hour and from day to day are large and sampling should be timed to incorporate typical conditions. The usual survey samples the wastewater discharge and measures the flow every hour during a three day period. Though these three days need not be consecutive, they must be when the amount of slaughtering, processing, and water use are normal in the plant.

Hourly samples are composited over one day in proportion to the flow at the time the sample was taken. (Thus if flow drops to near zero during the night as is the case in small plants, samples need not be taken). The samples are kept refrigerated and analyzed the next day.

The information gathered for the preliminary design of the demonstration facilities at the W. E. Reeves Packing Co. is given as an example. This small plant slaughters about 500 cattle and 700 hogs per month and processes about 30 items. The wastewaters come from the slaughtering area, the meat processing areas, the lavatory, the hide storage cellar, and the holding pens. The major waste load is from slaughtering which is a one-shift operation, Monday through Friday. Meat processing is extended until noon on Saturday. The hide cellar is emptied and flushed once a month and the holding pens are dry cleaned and then flushed on Saturday.

Both wastewater flows and concentrations were measured in the survey. Eight hourly samples were taken and composited during slaughtering/processing on May 19, 1970, and on June 9, 1970. A grab sample was taken on June 19, 1970. The samples were analyzed according to Method for Chemical Analysis of Water and Wastes, EPA 625/6-74-003. The data are tabulated in Table 3.

Table 3. Wastewater Chemical Analyses for Preliminary Design

Parameter	May 19, 1970	June 9, 1970	June 19, 1970
BOD_5	2680	1352	1165
Grease	1823	434	--

The BOD_5 and grease data exhibit the large variation found in slaughterhouse wastes. A BOD concentration of 2000 mg/l was selected for design purposes. The temperature of the wastewater was 25° to 28°C. To measure flow, a Parshall flume with a 3-in. throat was installed with a recording flow meter. The flow measurements are shown in Table 4. A flow of 15,000 gallons/day was used for design purposes.

This survey proved to underestimate the flow and overestimate the BOD_5. During the following year, weekly measurements showed an average BOD_5 and flow of 1247 mg/l and 17,800 gal/day, respectively. Compositing samples taken every half-hour from 6 a.m. to 6 p.m. (the total time personnel were in the plant) would have improved the measurement of BOD. Comparing long-term water meter readings with those when the wastewater volume was measured would have improved the estimate of flow.

Table 4. Wastewater Flow Analyses for Preliminary Design

Date		Flow (gallons)	Operating Period (hrs)
6/18/70	Thursday	19,152	8
6/19/70	Friday	15,072	8
6/20/70	Saturday	2,495	3
6/22/70	Monday	14,040	9
6/23/70	Tuesday	15,498	9
6/24/70	Wednesday	14,274	10
Total	1 week	80,531 gallons	47 hours.

Only the parameters used in design need to be measured. Flow and BOD_5 are used in design of all biological treatment processes. Grease measurements are important to determine the need for a grease trap. There are other parameters that are needed for specific treatment processes. The most important of these are sulfate (if an anaerobic lagoon is being considered) and sodium, chloride, and total nitrogen if a land disposal system is being considered. The source of the sulfate is the water supply and the concentration can be obtained from the municipality or by analysis of the well water. Sodium, chloride, and nitrogen need to be measured in the wastewater stream because their major sources are slaughtering and hide curing.

Site Selection

Selection of the site and selection of the processes to be used in the treatment system are usually done concurrently. However, for small plants available land and operational requirements narrow the alternatives. The first choice is to build or buy a treatment system. Where sufficient land (1 to 20 acres) can be used for a treatment plant site, then the technology reported herein can be utilized. Where land is not obtainable or where zoning is restrictive, then purchase of a compact package treatment system can be a solution. This option is not covered herein, but information can be obtained from the manufacturers of such plants. If suitable land is available, the treatment processes which plant personnel can construct are lagoons, sand filters, and facilities for land application. The physical requirements of these processes should be used to judge the suitability of the available sites.

The Reeves plant is located on 64 acres of rolling land, one mile west of the city limits of Ada, Oklahoma. An unnamed creek flows north through the property. The prevailing winds are from the south. North of the plant are cattle ranches with the nearest residence located 1.5 miles from the plant. South and southwest of the plant the nearest residences are 0.25 mile distant. In addition to the processing plant, cattle pens, storage areas for machinery and materials, and parking areas are located on the grounds.

An inspection of the 64 acres revealed several potential sites for a treatment system. The sites adjacent to the plant were used for holding and feed pens, and storage of materials and equipment. These were eliminated as potential sites because of relocation costs and priorities of the ongoing uses. The site selected was a 22 acre pasture and solid waste disposal area which was 300 feet west of the plant. This site permitted a gravity flow system eliminating the necessity for a pumping station. The disadvantages were land slope and a conglomerated rock layer immediately under the surface. The site had sufficient land available for selection of lagoons or an irrigation system. The trade off of land value for the costs of concrete and steel in more compacted systems was possible, and plant personnel were capable of constructing a lagoon or irrigation system.

Process Selection

The first consideration in process selection is reduction of the quantity of pollutants to levels meeting discharge requirements. This includes reduction of BOD_5, suspended solids, and grease if the discharge is to a municipality. If the discharge is to a surface water, additional limitations exist on pH and fecal coliforms. Ammonia limits are applied to new sources of discharge or where water quality standards control and are expected on all discharges to surface waters by 1983.

Before looking at the capabilities of the numerous treatment processes, some special needs of small plants need to be considered. These needs reduce the number of processes to be considered. Because the use of full-time waste treatment personnel is not practical for small plants, minimum operational requirements are more important than minimum capital or power costs. For example an annual cost of about $6,000 was incurred on each of several different treatment systems demonstrated at the Reeve's plant which included about $2,000 for operation and monitoring. These data indicate operation and monitoring costs to be an extremely high percent of total cost for small plants, and the importance of minimizing manpower requirements.

Processes to be considered for small plants are limited to those that require less than eight hours per week for operation and maintenance, that minimize and automate mechanical equipment, that prevent undetected failures, and that allow simple construction to reduce the initial capital requirements. These requirements encompass the anaerobic lagoon, the aerobic lagoon, an unusual extended aeration lagoon, intermittent sand filtration, and land application processes. The last two types of processes are described more fully in reports by Rowe and Tarquin in this publication. The effectiveness of all of these processes has been established by recently completed or ongoing EPA Research and Demonstration projects.

Anaerobic Lagoons

The anaerobic lagoon is the treatment process most widely used at meat and poultry plants. The anaerobic process is especially suited to the concentrated hot wastewaters from these plants. The process utilizes anaerobic bacteria, which function in the absence of free oxygen to break down organic wastes. The lagoon is usually deep and covered with a blanket of floating sludge.

The anaerobic lagoon has obtained greater than 90 percent BOD_5 reduction, with highest removals during the hot summer. The process has the desired minimum capital and operating costs, is simple to operate and shows visible treatment results; mechanical equipment is not necessary and the treatment processes can withstand the shock loadings common to the industry. The anaerobic lagoon has given high removal efficiency with and without sludge recirculation. The benefits of sludge recirculation were outweighed by maintenance problems at the Reeves plant. Elimination of sludge recirculation results in a desirable reduction in manpower and capital requirements for the small plants.

Two potential problems must be evaluated prior to selection of the anaerobic lagoon. These are odor emissions and discharges of ammonia. The sulfate in the water is reduced under anaerobic conditions to hydrogen sulfide, and the protein in the wastewater is reduced to ammonia. In some cases, a sulfate concentration of over 200 mg/l in the water supply has resulted in such objectionable odors that the process was abandoned. Even without sulfate in the water, some odors may occur. Location of the facility at least 1/4 mile from a single home or 1/2 mile from a residential area is suggested.

Ammonia is toxic to fish, and fish kills due to ammonia in meat plant discharges have been documented. However, reduction of protein to ammonia is a reaction that cannot be avoided in biological systems. The problem is that the concentration of ammonia in anaerobic lagoon effluents requires the selection of additional treatment processes that remove the ammonia.

Anaerobic lagoons are designed with a low surface area to volume ratio to conserve heat and minimize surface reaeration. Depths of 10 feet or more are desirable. Economic considerations and maintaining several feet above the groundwater usually limit depths to less than 18 feet. The volume is based on organic loading and designs range from 12 to 25 pounds of BOD_5 per 1000 cu. ft. with 15 lbs. BOD_5/1000 cu. ft. being common. The anaerobic lagoon at the Reeves plant had a water depth of 10 feet and an organic loading of 12 lbs. BOD_5/1000 cu. ft. Removal efficiencies for BOD_5, TSS, and FOG were 92, 84, and 95 percent, respectively. The consistency of the effluent (Anaerobic Effluent) concentration for BOD_5, Chemical Oxygen Demand (COD), TSS and NH_3-N can be seen in Figure 1. These frequency vs. concentration graphs display the reliability of the anaerobic pond for treatment of these wastewaters.

As previously stated, the parameters used in determining municipal sewer rates are generally BOD, TSS and Oil and Grease. Figure 1 shows that the BOD and TSS will be below 200 mg/l except on rare occasion. Oil and grease analyses made on the effluent show the concentration is well below the 100 mg/l limit commonly used by municipalities. The high percent removal and consistency of effluent concentration from the anaerobic lagoon result in an effluent which would meet common limitations for discharge to a municipal treatment plant.

Discharge of an effluent with high hydrogen sulfide concentrations to a municipal system will result in damage to concrete sewers and structures unless precautionary devices are installed. Hydrogen sulfide, with the characteristic rotten egg odor, can be detected at low concentrations. At the demonstration facilities, the sulfate concentration in the water supply was 4 mg/l and a hydrogen sulfide odor could not be detected. Other septic odors could only be detected within 50 feet of the anaerobic pond in the downwind direction.

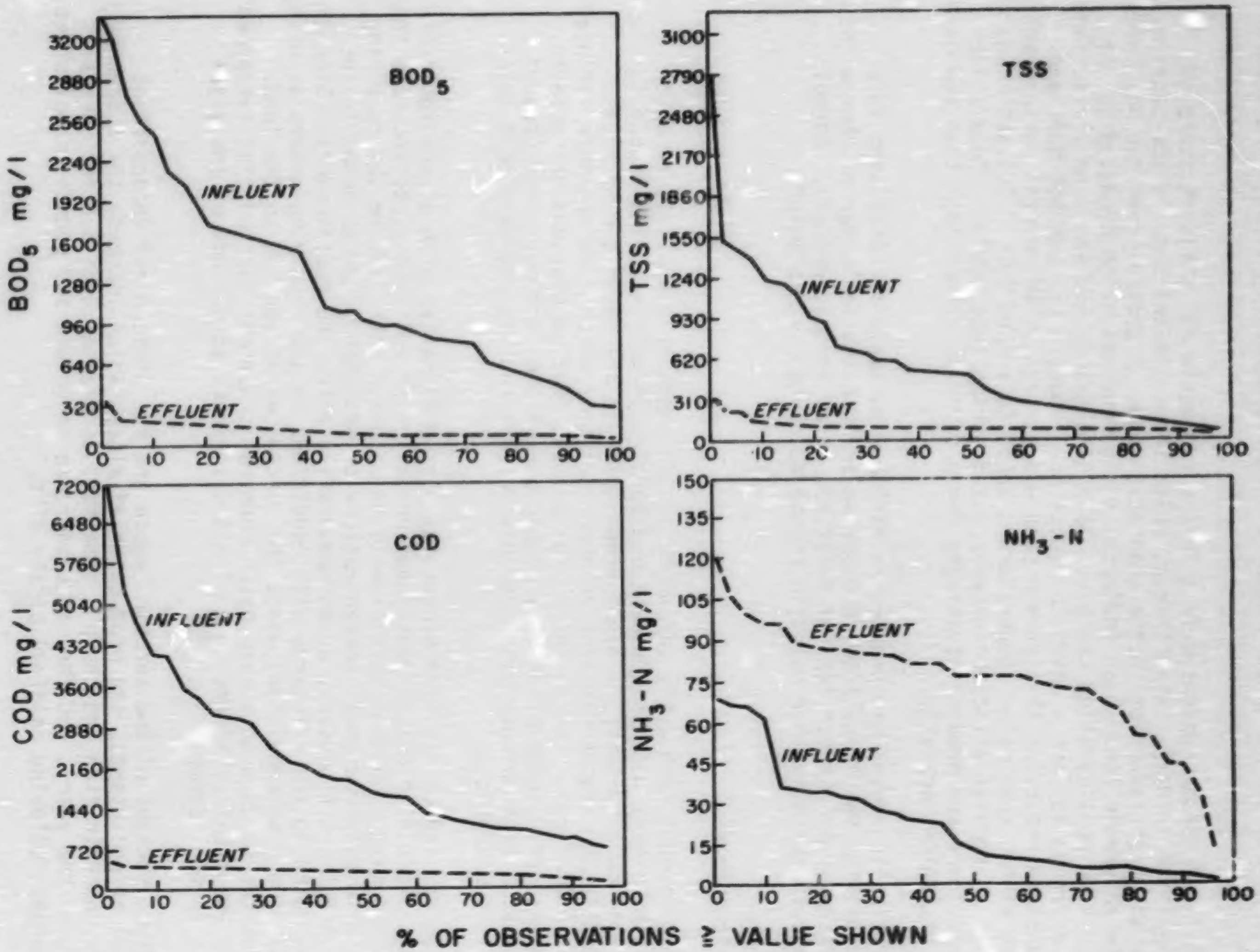


FIGURE 1 - ANAEROBIC LAGOON - FREQUENCY VS. CONCENTRATION

The increase in NH_3-N is displayed in Figure 1; most of the effluent concentrations were between 65 mg/l and 85 mg/l. The conversion of protein to ammonia increases the concentration of ammonia threefold through the anaerobic pond.

The oil and grease concentrations in the raw waste and effluent averaged 514 mg/l and 16 mg/l, respectively, which shows limited loss in the packinghouse and high reduction in the anaerobic pond. A grease cover did not form on the anaerobic pond which indicates the grease was being digested in the pond. Some consideration was given to mixing grease and straw on the surface of the lagoon to form a cover to reduce heat loss. This was not done and temperature reduction through the pond was as high as 60 percent during part of the winter when water temperature dropped to around 10°C. Insignificant changes in removal efficiencies were noted during this period. In a colder climate there are greater advantages for a cover to reduce heat loss and maintain biological activity.

The anaerobic lagoon can produce an effluent suitable for discharge to a municipality, but it will not produce an effluent suitable for discharge into a surface water without further treatment in an aerobic process. Aerobic processes are those that maintain dissolved oxygen in the water.

Aerobic Lagoons

Aerobic lagoons frequently called oxidation ponds or stabilization ponds, have been widely used by the meat and poultry industries. The lagoon is similar to a shallow lake having a light green color in the water due to algae. Frequently the discharges from an aerobic lagoon exceed the new more stringent NPDES limitations. Consequently, the process must be upgraded or replaced. Upgrading can be accomplished by either operational schemes or subsequent processes. Both methods are under development and will be mentioned later in this publication.

The aerobic lagoon has been successfully used in series with an anaerobic or aerobic process to obtain additional reduction of pollutants, to increase the dissolved oxygen content sufficiently to maintain fish life in the receiving waters, to dilute unusual concentrations of pollutants due to upset in the prior treatment processes, or to temporarily store the wasteswaters. Storage allows matching the discharge with conditions in the receiving waters or with weather and crop conditions where the wastewater is applied to the land. Storage can be used to enable batch chemical treatment for reducing suspended solids and fecal coliforms or to limit discharges to periods of low algae levels in the lagoon.

The disadvantages of the aerobic lagoon are the limited and inconsistent removal of pollutants, the production of algae (which increase the suspended solids concentration and the pH, sometimes to greater than 9.0 for several months of the year), and the large increase in volume and pounds of pollutant discharges following rainfall at the site.

The design of aerobic lagoons is based on daily pounds of BOD_5 per acre of water surface and a minimum 3 foot water depth to prevent weed growth and the subsequent production of mosquitoes. Frequently two or more aerobic ponds are used in series. The generally accepted loadings range from 20 to 40 lbs BOD_5/day/acre which is similar to design of the process for municipal sewage. However, aerobic operation has been achieved with loadings three times the above in lagoons treating meat packing wastewaters.

Because of the strength of the wastewater from meat and poultry plants, the aerobic lagoon must follow prior treatment to meet the design requirements. Thus the reduction of BOD_5 in the prior process must be estimated. State regulatory agencies and designers sometimes insist on a conservative estimate to provide a margin of safety. For example, state regulatory agencies in Illinois, Iowa, Nebraska, Tennessee, Pennsylvania, and Minnesota allow 60 percent BOD_5 removal when the prior treatment is an anaerobic lagoon loaded at 15 lb. BOD_5/1000 cu. ft.

The demonstration project was a two phase study. In the first phase, the two aerobic lagoons were operated in series following an anaerobic lagoon. In the second phase, the two aerobic lagoons were operated in series following an extended aeration process. The organic loading of the first and second aerobic lagoons averaged 52 and 8.5 lbs. BOD_5/acre/day, respectively, when preceded by an anaerobic lagoon; when preceded by the extended aeration unit the loadings were 8 and 5 lbs. BOD_5/acre/day, respectively. Detention times in the first and second lagoons were 30 and 84 days, respectively.

The consistency and degree of removal of BOD_5 and TSS for the two aerobic lagoons in both phases of the project can be seen in Figures 2 and 3. Following the anaerobic lagoon the first aerobic lagoon reduced the concentration of BOD_5 and TSS by 53 and 25 percent, respectively. The first lagoon decreased the average discharge of these pollutants sufficiently to meet 30 day average BPT limitations for 1977; however, the maximum day limitations were exceeded. The opposite occurred during the second phase of the study. Following extended aeration, the first aerobic lagoon generally increased the 30 day average concentration of BOD_5 and TSS, but reduced the highest daily concentrations of TSS from the extended aeration process. This reduction of TSS resulted in a discharge that meets the maximum day limitation for 1977. The 1977 limitations shown on Figure 2 are based on average flow and LWK values.

The second aerobic lagoon resulted in minor changes in BOD_5 concentration in both phases of the project (Figure 3). In the first phase, the TSS was significantly increased in the second aerobic lagoon. With respect to the National Effluent Guidelines, the most significant effect was the increased discharge volume after rainfall which on a few occasions increased the quantity of pollutants discharged to twice the maximum day limitation for TSS.

National Effluent Guidelines on pH and fecal coliform were established between the first and second phase of the demonstration project. In the second phase, the maximum pH limit of 9.0 was exceeded by both aerobic lagoons. The discharge from the first aerobic lagoon exceeded the pH limitation three out of 45 measurements. These three samples were all taken in April. The discharge from the second aerobic lagoon exceeded the pH limitation 15 out of 46 measurements.

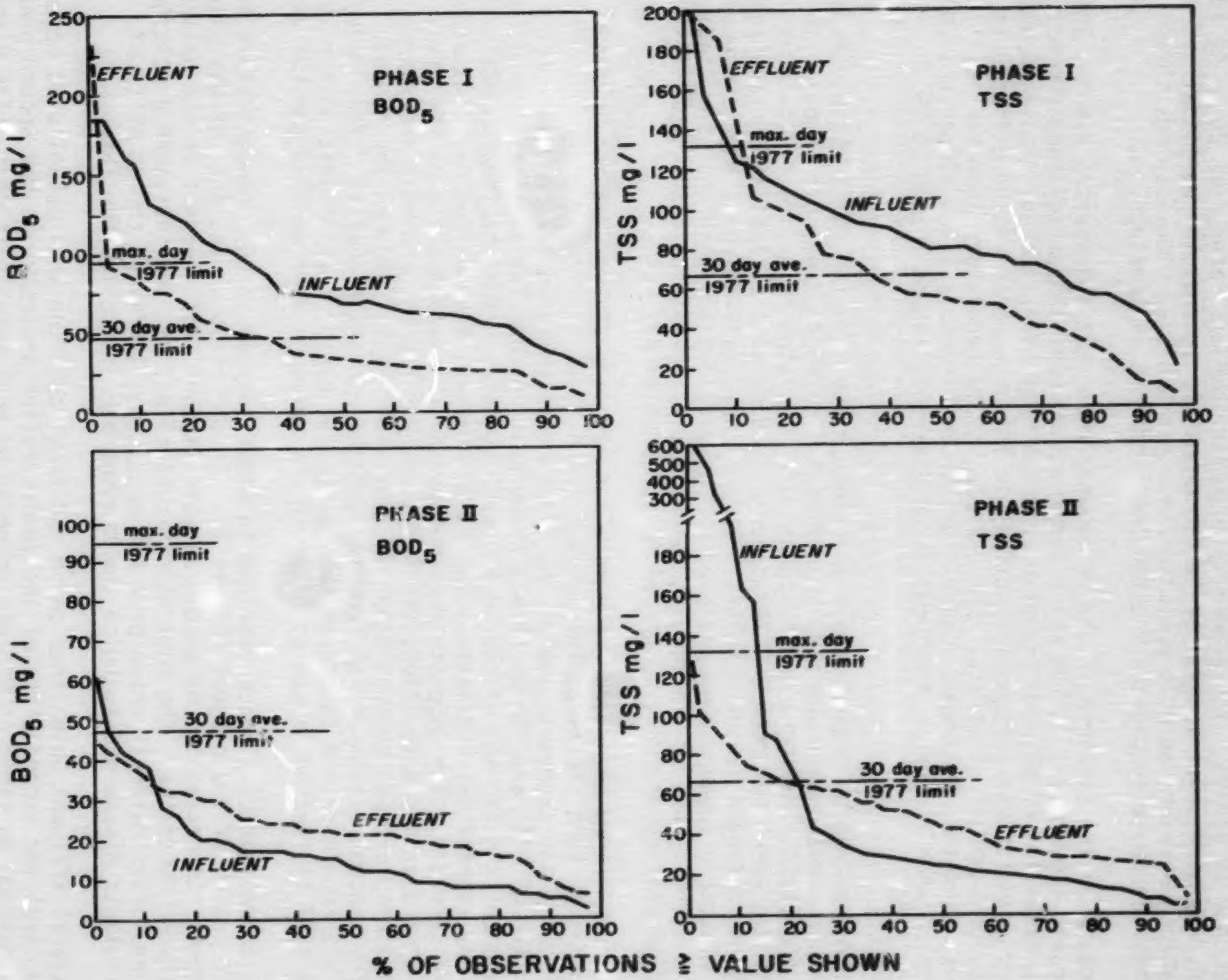


FIGURE 2 - FIRST AEROBIC LAGOON - FREQUENCY VS. CONCENTRATION

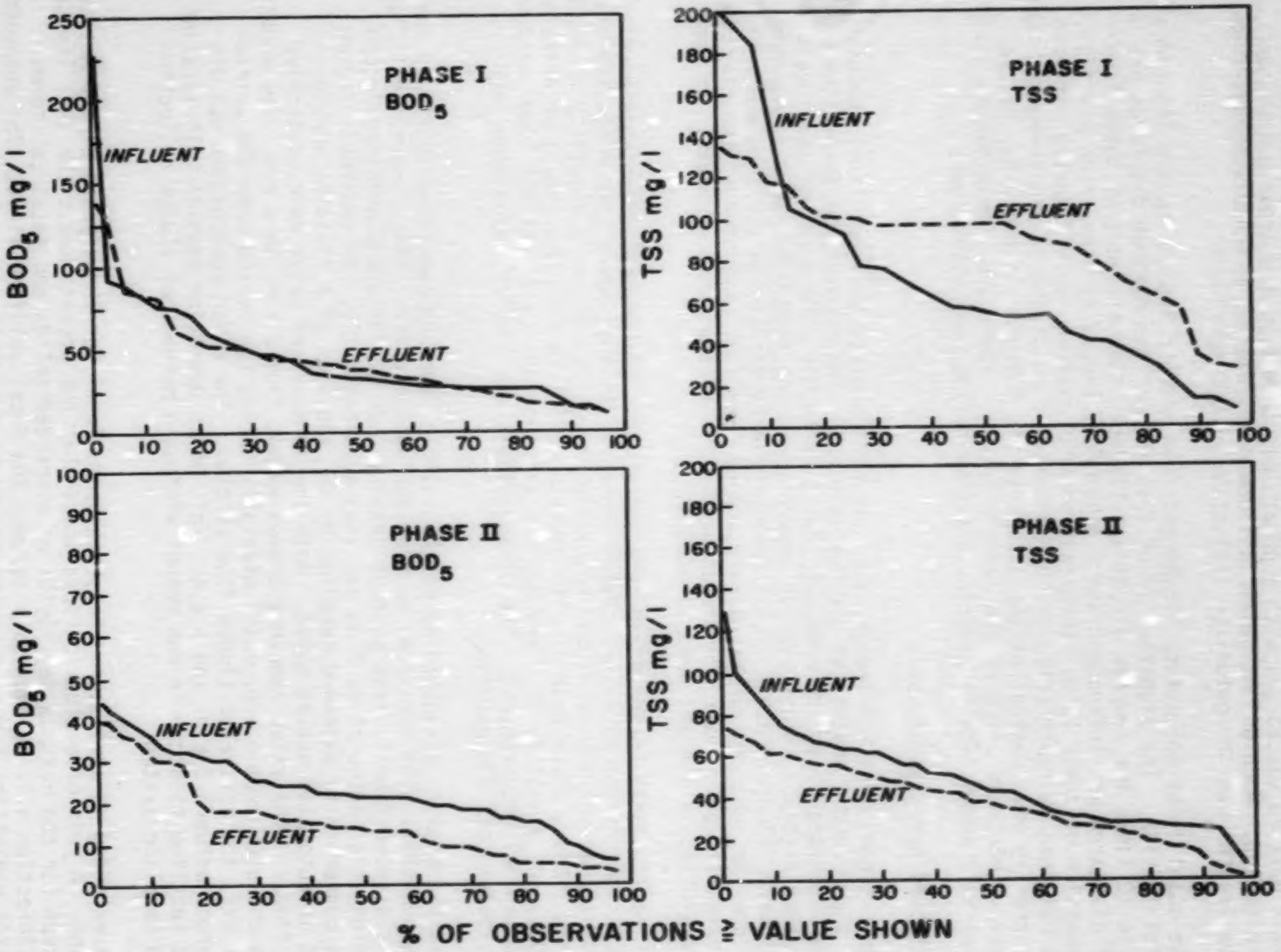


FIGURE 3 - SECOND AEROBIC LAGOON - FREQUENCY VS. CONCENTRATION

All 15 samples were taken during the warm months, July through October. There were no discharges with a pH of less than 6.0, the lower guideline limitation. None of the fecal coliform measurements on the discharges from the lagoons met the guideline limitation of 400 mpn/100 ml.

The quantity of pollutants discharged from aerobic lagoons have a log normal distribution. The significance of this is that the maximum discharge can be 5 to 10 times the average discharge; however, the occurance of these levels of discharge are infrequent and are commonly caused by heavy precipitation. Reduction of these large discharges to meet maximum day effluent limits can be obtained by restriction of the volume of flow discharge and temporary storage in the lagoon. Control of the discharge via temporary storage may be the most valuable function of the aerobic lagoon. There are simple outlet designs that will automatically restrict the flow during peak discharges.

Extended Aeration Lagoon

The extended aeration lagoon is a treatment process that was first demonstrated on the research project at the Reeves plant. The process, an adaptation of the activated sludge process, was designed to meet the needs of small meat and poultry plants. The process incorporates in one lagoon the common sequence in the activated sludge process, i.e.. growth of a bacterial floc, mixing and aeration of the floc and wastewater, separation of the floc, discharge of the clarified wastewater, and return of the bacterial floc to the aeration basin. In appearance the process is a small-deep aerated pond.

For small plants the extended aeration process has several advantages over other variations of the activated sludge process. It produces a higher quality effluent and smaller volumes of sludge requiring disposal. It has the ability to handle shock loads and can both nitrify ammonia (NH_3^-) to nitrites (NO_2^-) or nitrates (NO_3^-) and denitrify NO_2^- and NO_3^- to nitrogen gas (N_2). It has lower manpower and capital requirements. The disadvantages are the increased power and equipment cost for aeration.

Meat and poultry slaughtering plants usually have one operating shift and one cleanup shift with little or no flow during the night. This intermittent flow is a disadvantage in most process designs. In the extended aeration lagoon design, the period of no flow was used advantageously. An anaerobic lagoon was converted to extended aeration by the addition of a floating aerator and an automated outlet valve. Both the aerator and valve were controlled by timers. The valve remained closed except from 2 a.m. to 6 a.m. The aerator was operated from 6 a.m. until midnight; during the period when the aerator was off, the activated sludge floc settled. The clear supernatent was discharged between 2 a.m. and 6 a.m. This batch Operation enabled both aeration and settling to occur in one vessel without a mechanical sludge collection and handling system.

The extended aerated lagoon has been operational for three years at the Reeves plant. A year of evaluation data shows that the process meets the 1977 limitations except for the maximum day limits on suspended solids and fecal coliforms. Disinfection will be necessary to meet the fecal coliform limit. The suspended solids violations occurred during the first two months of evaluation because of unusual operating conditions which included a new operator, freezing weather, sludge wasting and excessive flow due to a broken water line in the plant.

The number of analyses (n), mean concentrations of pollutants in the influent and effluent, and removals by the extended aeration lagoon are given in Table 5. The removal efficiencies based on mean concentrations of BOD_5, COD, FOG, NH_3-N, and Total Kjedhal Nitrogen (TKN) exceeded 90 percent. Removal of TSS was 96 percent when based on median concentrations. After the first two months of the study period the TSS in the effluent dropped from around 200 mg/l to about the median value of 23 mg/l. Removal of Total Phosphate (T-P) was lowest at 71 percent; however, no T-P was removed when this unit was operated as an anaerobic lagoon. The maximum discharge of NH_3-N was 7.0 mg/l, except for 4 days when the aerator was off due to vandalism. Both NH_3-N and TKN concentrations decreased in the unit with only 2 percent of the decrease accounted for by the increase in NO_2+NO_3-N. Denitrification occurred, most likely during the 6 hours each day when the aerator was off. Within the pH range of 7 to 8 only 20 percent of the ammonia was in a form that could have been lost to the atmosphere. The odors of ammonia or other objectionable compounds, e.g. hydrogen sulfide or mercaptans, were not detected.

Table 5. Concentrations and Removals - Extended Aeration

Parameters	n	Influent (mg/l)	Effleunt (mg/l)	Removal (%)
BOD_5	42	714.8	17.0	98
COD	46	1630.2	121.6	93
TSS	45	535.8	65.4	88
FOG	10	138.6	11.9	91
NH_3-N	44	12.5	1.9	95
NO_2+NO_3-N	44	0.4	2.6	--
TKN	46	79.0	7.8	90
T-P	46	11.0	3.3	71

The extended aeration unit was organically and hydraulically loaded lower than usual in this country. The loadings are common for oxidation ditches used in The Netherlands. The food to microorganism ratio (F/M) averaged 0.06 lb BOD_5/lb Mixed Liquor Volatile Suspended Solids (MLVSS). The mean hydraulic detention time was 9.8 days and sludge retention time (SRT) averaged 64 days. Sludge was wasted five times during the 12 month study period. Mixed Liquor Suspended Solids (MLSS) averaged 3350 mg/l and the Sludge Volume Index (SVI) averaged 217.

A previous study evaluated the extended aeration process at a packinghouse in Iowa. In that study the F/M averaged 0.26 lb BOD_5/lb MLSS and the detention averaged 3.6 days. The effluent concentrations for BOD_5, TSS, FOG, and NH_3-N averaged 70, 142, 21 and 18 mg/l, respectively. Both the loadings and the effluent concentrations were several times greater than in this study. With those higher loadings the extended aeration processes exceeded the 30 day 1977 limitations for BOD_5 and TSS five and seven fold, respectively.

Aerated Lagoons

The aerated lagoon is described because the process is widely used in the meat and poultry industries. The process can achieve average BOD reductions of 50 to 60 percent. The process is similar in appearance to the extended aeration lagoon previously described but does not have a controlled discharge or scheduled aeration. Thus the process does not separate the biological floc from the effluent and is usually followed by another process to capture the suspended solids which are created. The ability to capture the biological floc in a several acre aerated lagoon by batch operation, demonstrated for small extended aeration lagoons, may not be possible. Thus the aerated lagoon has more potential value for large plants than it does for small plants. The aerated lagoon has been used for pretreatment prior to discharge to a municipality or as a process between an anaerobic lagoon and an aerobic lagoon.

Some aerated lagoons are aerobic lagoons upgraded by the addition of aeration equipment, but the usual design is for a deeper lagoon--between 8 and 15 feet. The increased depth gives more efficient use of the aeration equipment and reduces energy and aeration equipment costs. However, usually the controlling design factor for aerators is the requirement for mixing the biological floc rather than the oxygen demand of the lagoon contents. Detention times ranging from 2 to 10 days have been used. The process was not evaluated for its application to small meat or poultry plants at the demonstration plant and will not be described further.

Intermittent Sand Filtration

The intermittent sand filtration process is used by more than a sozen small meat plants in Ohio and has had widespread use following aerobic processes treating domestic sewage from institutions and subdivisions. The process requires simple and infrequent maintenance which is important to small plants. Intermittent sand filtration has been used for nearly a hundred years for treatment of sewage; however, the increasing volumes to be filtered and the rising cost of land have reduced its use. For large plants, rapid sand filtration preceded by chemical treatment would be more practical due to the savings in land and manpower, but rapid sand filtration with chemical treatment would be likely to fail unless a full-time operator is employed.

The intermittent sand filter has the capability of upgrading discharges from several treatment systems to meet the 1977 National Effluent Guidelines for suspended solids. Suspended solids and fecal coliforms are the two limitations that most of the present treatment systems fail to meet.

The intermittent sand filter resembles a lagoon filled with sand. A layer of gravel with drain pipes is under the sand to collect the filtered wastewater and discharge it through the lagoon dikes. The filter is designed on the basis of hydraulic loading per unit of sand surface area, and on effective size of the sand particles. Loadings of 0.2 to 1.2 million gallon/day/acre (mgad) and effective sizes of 0.2 to 0.7 millimeter (mm) have been used. Pilot scale experiments at the demonstration plant used a loading of 0.5 mgad and sand of 0.2 mm. Removal of BOD_5 and TSS were about 70 and 50 percent, respectively. Further description of the design and effectiveness of a full-scale filter is presented by Dr. Rowe in this publication.

Land Application

Land application actually encompasses three treatment processes which have been utilized by food processors for several decades. The use of land application is expected to increase dramatically by 1983 when Best Available Technology Economically Achievable guidelines are applied or sooner where similar limitations are required because of water quality standards.

The three treatment processes are infiltration, irrigation, and overland flow. Selection of a process is primarily governed by the drainability of the soil at the available site, which largely determines the hydraulic loading and the required land area. The comparative characteristics of the three processes are presented in Table 6.

Table 6. Characteristics of Land Application Processes

Design Factors	Infiltration	Irrigation	Overland Flow
Loading (in/day)	0.6 to 19	0.1 to 0.6	0.25 to 1.0
Land area (acre/mgd)	Less than 60	60 to 370 plus buffer zone	50 to 150 plus buffer zone
Drainability, soil type	Rapid, Sands to sandy loam	Moderate, Loamy sand to clay	Slow, Clay loam and clay
Application Technique	Spray or surface	Spray or surface	Spray

The infiltration process depends upon the applied wastewaters percolating through the soil and eventually into the groundwater. The process is restricted to rapidly permeable soils and to wastewaters which will not plug the soil. Meat and poultry processing wastewaters may require prior treatment to remove particulates and grease.

The irrigation process involves application of wastewater to maintain or increase crop production. The objective of most meat and poultry processors is only to maintain crop production while maximizing hydraulic loading. This operation requires smaller storage facilities and irrigation area. The soils often contain clay and the sodium content of the wastewater can cause plugging of the soil. High chloride in the wastewater can also cause damage to the crop growth. When using an irrigation process, in-plant process control to reduce salt loss should be incorporated.

Overland flow is a process in which wastewater is applied at the top of smoothly-sloped, plant-covered land and collected at the bottom of the slope for discharge. The process depends mainly upon bacteria on the slope to reduce the pollutants in the wastewater and upon loss of volume due to evaporation. The concentration of salt in the wastewater may cause the same problems as in the irrigation process.

Because of the potential health hazard caused by the addition of nitrites (NO_2^-) to the groundwater, some States put limits on the amount of nitrogen per acre per year that can be applied to land. The usual concentration of nitrogen in meat and poultry wastewaters can exceed these limits when applied at the loadings shown in Table 6. In these States, partial removal of nitrogen from the wastewater may be necessary prior to land application.

Both the irrigation process and infiltration process can achieve "no discharge to surface waters." Thus not only could these processes meet the 1977 and 1983 National Effluent Guidelines, but there would be no monitoring expenditures unless required by a State agency. The overland flow process produces a surface discharge and was, therefore, evaluated at the demonstration project. The process was evaluated on a raw wastewater receiving screening and aerated storage, on a wastewater treated in an anaerobic lagoon and on a wastewater treated in an extended aeration lagoon. The overland flow process preceded by an anaerobic lagoon met the 1977 limitations for BOD_5 and TSS but did not meet the 1983 limits because discharges of NH_3-N averaged 20 mg/l. The overland flow process preceded by either screening or extended aeration met the 1977 National Effluent Guidelines and could meet the 1983 limits if provisions are made for control of the discharge volume with partial recycle to the irrigation area during intense rainfalls. Thus the process could be designed to meet both 1977 and 1983 National Effluent Guidelines. Fecal coliform measurements showed that the discharge from the process needed to be disinfected.

Further description, design and construction consideration of land application processes will be presented by Dr. Tarquin in this publication.

Disinfection

Disinfection is a process which eliminates microorganisms to prevent the spread of disease by protecting public water supplies, aquatic life, bathing beaches, etc. National Effluent Guidelines include a limit on fecal coliform of 400 mpn/100 ml. Fecal coliforms are an indicator organism for the presence of bacteria of a human origin. None of the treatment processes evaluated at the demonstration project meet this limitation. Consequently, the addition of a disinfection process is necessary where the limitation is imposed.

Treated wastewaters may be disinfected by several chemical or physical processes; however, chlorination is used almost exclusively. Chlorination of treated wastewater consists of the addition of 5 to 15 mg/l of chlorine in a basin having about 30 minutes detention. The amount of chlorine required varies with the degree of prior treatment. Of special concern with meat and poultry wastewaters is the concentration of ammonia in the discharge. Chlorine combines with ammonia and reduces the disinfection ability of the chlorine. For every mg/l of ammonia, several additional mg/l of chlorine will be needed to reduce the fecal coliform to the required level. Chlorine requirements are usually established in a laboratory by measuring the remaining fecal coliforms or the chlorine residual 30 minutes after addition of the chlorine.

Dosages of chlorine are usually kept constant during periods of discharge for small plants. The cost of extra chlorine does not justify the cost of automatic equipment to change chlorine dosage with chlorine demand. The three methods of application for small plants are the addition of chlorine from a pressure cylinder, addition of hypochlorite with a dry chemical feeder, or addition of chlorine generated with an electrolytic cell and brine solution. The chemical feed and electrolytic cell require electrical power and can be automated to operate in synchronization with controlled releases. For small plants the most common method is the use of liquid chlorine from 100 to 150 lb steel containers.

Cost Estimates

Minimization of cost while meeting the discharge, monitoring, and site constraints is the primary purpose of preliminary design. The selection of treatment processes determines not only the capital cost but also the operation, maintenance and monitoring costs. The selection of processes which substitute land for building materials, mechanical equipment, operational requirements, and even monitoring requirements is common with food processors, especially small plants.

More stringent discharge requirements can be expected with time and increased population. The present National Effluent Guidelines are scheduled to become more stringent in 1983. Selection of treatment processes and site should be based on the ability to meet more stringent requirements. There should be the capability of adding facilities or upgrading processes. For example, the anaerobic lagoon can be converted to an extended aeration process. The aerobic lagoon can be converted to an intermittent sand filter or to a storage facility for application of the wastewater to land.

The nine treatment processes which have been described are especially suited to the needs of small plants. All of the processes described could be built utilizing plant personnel and earth shaping equipment. The processes described can meet the common requirements for discharge to a municipality or the requirements under the National Effluent Guidelines for 1977 or 1983. At the demonstration plant, two treatment systems have been shown capable of meeting each of these three discharge requirements. For a discharge to a municipal sewer either the anaerobic lagoon or the extended aeration lagoon could be used. For a discharge to meet 1977 National Effluent Guidelines either an anaerobic lagoon plus overland flow and disinfection or an extended aeration lagoon plus intermittent sand filtration and disinfection could be used. For a discharge to meet 1983 National Effluent Guidelines either screening and aerobic storage plus overland flow and disinfection or extended aeration lagoon plus overland flow and disinfection could be used. Other combinations of these processes and additional processes, especially land application by irrigation or infiltration, are also capable of meeting these requirements but are not covered here.

The major costs involved with constructing the processes described are in decreasing order of investment: land, earth movement, the needed materials (pipe timers, pumps, motors, valves, sand, gravel and concrete) and aeration equipment. The last two items could be determined accurately regardless of location but the first two, land and earth movement, are highly dependent on the site selected.

Thus cost estimates for selection of a treatment system or for obtaining funding must be made for an individual site. However, capital costs and land requirements have been determined on these systems at the Reeves plant and are shown in Table 7.

Table 7. Costs at Demonstration Site

Facility	Capital Needed ($)	Land Needed (acres)
Sewer & Manholes	2,000	0.1
Anaerobic Lagoon	6,000	0.3
Aerobic Lagoon	12,000	1.5
Extended Aeration Lagoon	12,000	0.3
Intermittent Sand Filter	13,000	0.3
Overland Flow (estimate)	6,000	5.0

The capital costs in Table 7 do not include cost for land but do show cost incurred for construction of the full-scale process at the Reeves plant. Overland flow is the exception and is an estimate based on pilot-plant data and site conditions at the Reeves plant. Preliminary costs can be estimated by comparing size or design factors of another plant with the Reeves plant. At the Reeves plant the wastewater flow averaged 18,000 gal/day and BOD_5 averaged 185 lb/day. There was 550 ft. of 6" diameter sewer pipe and three manholes. The maximum centerline height of the dike in the anaerobic lagoon was 13 feet. The aerobic lagoons hold four months of flow and would be similar to the cost for aerobic storage needed in northern climates to limit land application (overland flow) to days when the temperature is greater than 32°F and there is less than 0.5 inches of rainfall. The extended aeration lagoon was previously the anaerobic lagoon with an automated 10 Hp aerator and outlet valve. The intermittent sand filter was designed at 0.5 mgad with 3 ft. of freeboard to handle heavy rainstorms. The overland flow was based on 5-day a week application with winter application of 0.25 in/day. The amount of land needed, as shown in Table 7, has been increased to include not only that for the process but also for auxiliary items, i.e. roads, pipelines, pump, control structures and fences.

The processes shown in Table 7 were selected for minimum maintenance and operation costs. The anaerobic lagoon and aerobic lagoon had less maintenance and power costs because of the absence of mechanical equipment (the aerator for extended aeration and the pumps for overland flow). Cleaning of the sand filter resulted in extra operational costs.

A comparison of the relative costs of a process or of a combination of processes in Table 7 will aid in minimizing capital and land needs. Using a ratio of the size of the demonstration facilities to those needed at another plant and data in Table 7 will permit an estimate of the funding requirements.

FUNDING

There is a difference between small meat plants and small poultry plants that becomes increasingly significant when funding is discussed. Poultry processing has become more highly automated. The typical small plant is a single-line plant which slaughters 20,000 to 30,000 chickens per day and has a wastewater discharge of about 200,000 gal/day. The small meat plant is commonly one that slaughters less than 25,000,000 lbs annually and has a wastewater discharge of less than 75,000 gal/day. A poultry plant processing 28,000 chickens/day will slaughter slightly less than 25,000,000 lbs annually but will discharge about three times the wastewater volume as a meat plant with the same annual kill. Though small meat and poultry plants have about the same quantity and kind of pollutants to treat, because of the larger volume requiring treatment the poultry processors funding requirements will be two to three times larger.

Funding is more than obtaining the money, though,for small businesses this may be a critical item. Governmental regulations which reduce the business' taxes or which lower the interest on the borrowed funds can be a significant part of funding.

The financial opportunities of using depreciation and investment tax credit and the relative cost of bank financing, Small Business Administration (SBA) loans and governmental low interest bonds are described in an EPA Technology Transfer Publication entitled, "Choosing the Optimum Financial Strategy--Upgrading Meat Packing Facilities to Reduce Pollution."

Conventional bank financing is the most common source of funds for small businesses. However, the Federal Water Pollution Control Act has authorized the Small Business Administration to assist small business concerns in adding to or altering their equipment, facilities, or methods of operation in order to meet water pollution control requirements established under the act. The loans are to provide relief to small businesses who might otherwise suffer substantial economic hardship without some financial assistance. SBA has three loan options available. They may guarantee up to 90 percent of a loan, enter into an immediate participation basis loan with a bank or make a direct loan. Within limits, the private lender sets the interest rates on the first two types of loans but on direct loans the interest rate corresponds to the average annual interest rate on all U.S. obligations. The environmental Protection Agency must perform a technical review of the application to determine that the proposed additions or alterations are necessary and adequate to meet the NPDES discharge requirements. For additional details contact either the nearest EPA Regional or SBA District Office.

State governments often have programs which affect funding. Some states exempt pollution control equipment or facilities from sales, use, and property taxes. More often states have a financing program which raises the required funds through state sponsored revenue bonds. The bonds bear a lower interest rate because the interest is not subject to the Federal income tax. For small plants, with capital requirements ranging from $25,000 to $250,000, the use of these bonds may not be practical.

DETAIL DESIGN OF LAGOONS

In this section, as in others, several lagoon based processes and their appurtenanc are stressed. The detail design of intermittent sand filters and land application processes are covered in this publication by Rowe and Tarquin, respectively.

Detail design means different things to different people. To a consulting engineer it means extensive plans and specifications suitable for control of a construction contract. To the manager of a small plant it means sufficient instruction to direct plant personnel or a subcontractor to construct a portion of the facilities. Drawings of the layout of the sewers, lagoons, inlets and outlets are helpful in preventing errors in elevation, alignment, and size. The drawings need not contain the details necessary for bidding by a contractor, but to eliminate drawings would be a serious error. Some States require industries to submit drawings from a licensed engineer for approval prior to construction.

Location

To determine the exact location of the lagoons at the demonstration plant a topographical map of the selected site was made. The map showed two foot contours and soil depth. The topography, and underlying rock of the selected site controlled most features of design. The limited soil at the site was mainly composed of decayed paunch contents and hair and was unsuitable for dike construction. A suitable clay soil that was being stripped to obtain underlying sand was purchased from a quarry approximately one-half mile from the site. The conglomerate rock at the site was from three inches to two feet under the surface. Dike height and the underlying rock were the controlling factors in location. To provide a minimum of three feet depth in the aerobic ponds removal of rock was necessary. The ponds were drawn on copies of the topography map at several elevations to calculate minimum cost of rock cut and dike full. As a result, the ponds were located as far up the slope as possible without eliminating a gravity flow system. The maximum depth of rock cut was 1.5 feet and maximum centerline height of the dike was 13 feet. A layout of the treatment system drawn to scale is shown in Figure 4.

Fortunately one of two potential locations for the deep anaerobic pond was in a draw which allowed construction of a pond with eight to ten feet of water depth without excavation of rock. Normally location in a draw would not be safe because of erosion problems from the intermittent stream flow. In this case a stock watering pond existed above the site. The dam on the pond was heightened two feet and the spillway structure was enlarged and shaped to divert any overflow past the lagoon location.

Size and Shape

The size of the lagoon in terms of volume, depth, or surface area is based on the design criteria given in the preliminary design section, i.e. organic loading, F/M ratio and minimum depth. Site conditions will influence the size within established limits of design. Construction techniques will also influence size. For example, the use of a bulldozer requires a minimum dimension of about 20 ft. in the lagoon bottom and this accompanied with the necessary dike slope and depth results in a minimum volume and dike length.

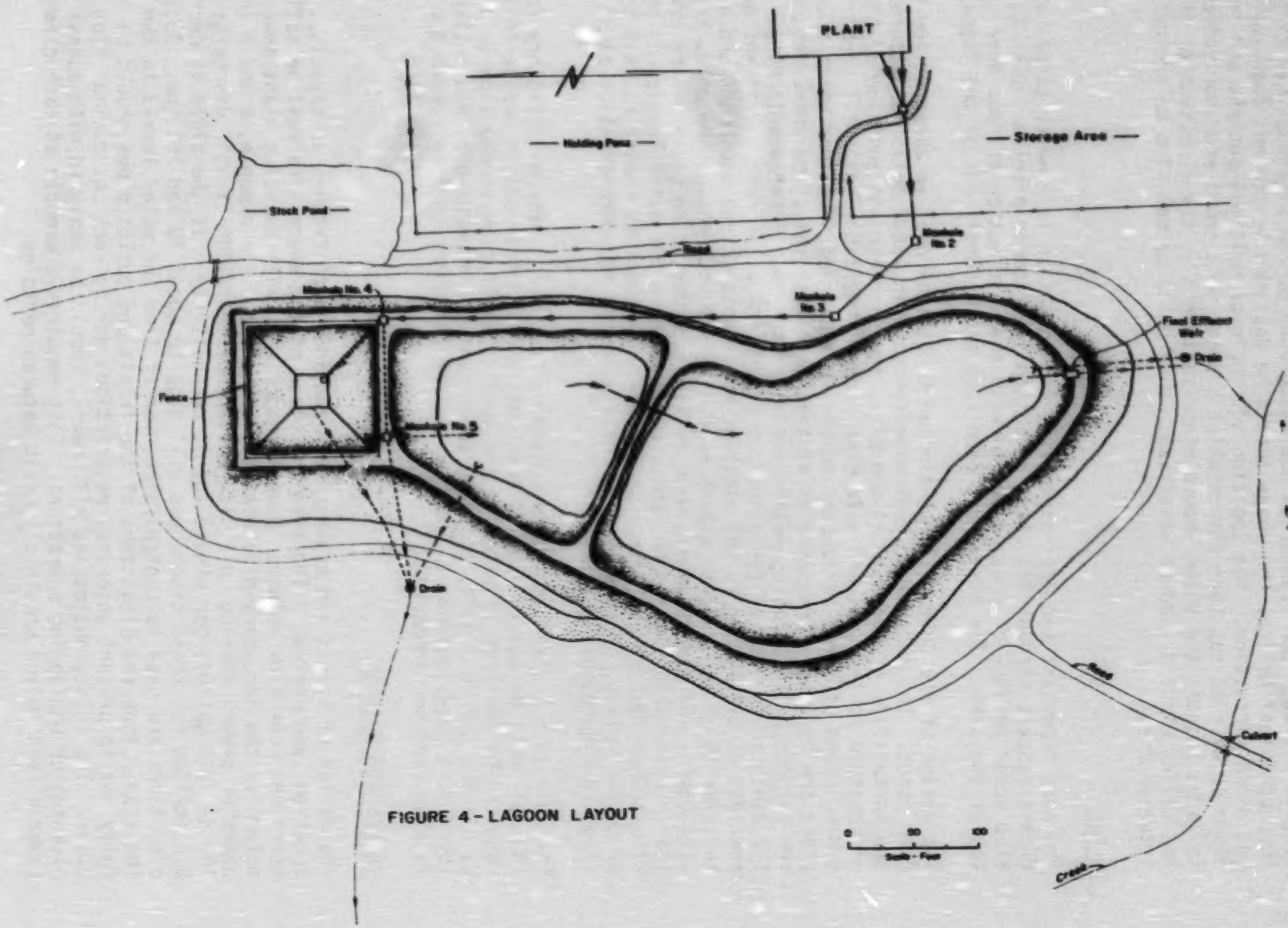

PLANT
N
Holding Pens
Storage Area
Stock Pond
Road
Manhole No. 2
Manhole No. 3
Manhole No. 4
Manhole No. 5
Fence
Final Effluent Weir
Drain
Drain
Road
Culvert
Creek
0
50
100
Scale - Feet

FIGURE 4 - LAGOON LAYOUT

Cost and construction technique usually result in square and rectangular shapes. Although the boundaries and topography of the site must be utilized for economical design, the shape should be designed to prevent dead spots and short circuiting. The location of single or multiple outlets and interior dikes or baffles can form shapes which prevent dead spots and short circuiting. In large lagoons the shape should minimize length in the direction of the prevailing winds to reduce wave size. Wave build up can also be prevented by interior dikes.

Dikes

The most important and most expensive item to obtain is a water tight basin. Excess seepage through the dikes or bottom is a common problem. Dike failures also occur because of erosion due to wind and wave action or flow over the top of the dike. The dikes must also keep storm runoff out of the lagoon.

The design of the dikes will be similar to designs used in construction of local farm ponds. The extension agent experienced with local soils can determine the suitability of the soil at the site, the need for the addition of clay or moisture to the soil and safe dike slopes. Suitable soil will support a dike slope of three horizontal to one vertical and sometimes up to a 2 to 1 slope can be used. Freeboard of at least two feet and often three feet above the lagoons peak operating water level are used to prevent overtopping. The width at the top of the dike is a minimum of eight feet. This not only provides stability but is the width of most construction equipment and allows the dike to be used for an access road. To prevent erosion the dikes are planted with grass. On lagoons where wave action is expected to cause severe erosion, the interior dike slope, one foot above and below the water levels, is protected with broken rock or concrete. Occasionally a wooden bulkhead, asphalt strip or cast-in-place concrete is used. The dikes at the demonstration plant are shown in Figures 5 and 6.

The soil in the dike must be compacted to be stable. For satisfactory compaction the soil must be moist. During the usual summer construction season this may require the addition of water to the soil. Satisfactory compaction is obtained by placing 0.5 to 1.0 ft. of soil, adding water, if necessary, and rolling the layer with heavy equipment. Frequently the bulldozer used to spread the material is also used for compaction.

Inlets and Outlets

The design of inlets and outlets must consider such factors as capacity, elevation, location, and control. The size and slope of the sewer line must be sufficient to carry the peak flow volume. Usually experience with existing plant sewers will determine the necessary pipe diameter and slope. For example, 6 and 8 inch diameter sewers flowing full with a slope of 1 ft/1000 ft will discharge about 100 and 220 gallons per minute (gpm), respectively. If the slope is decreased to 0.5 ft/1000 ft. these discharges will drop to about 70 and 150 gpm. Outlet elevations are used to control direction of flow and water levels in the lagoons. The size, slope and elevations of the inlets and outlet pipes should be carefully set to prevent undesired restrictions during peak and minimum flow conditions. The inlet, outlet and all sewers, should be designed with access for cleaning or unplugging operations. This requires a manhole at each change in sewer direction and smooth alignment between manholes.

FIGURE 5 - ANAEROBIC OR EXTENDED AERATION LAGOON

FIGURE 6 - FIRST AEROBIC LAGOON

At the demonstration site a manhole was placed at the edge of the lagoon. The sewer line grade board marks the location in Figure 5. The manhole outlet invert was set 0.1 feet lower than the inlet invert and a difference of 0.5 feet was set between the outlet in the manhole and the water level in the pond. These energy drops were to prevent plugging of the 6-inch pipe by the large particles in the raw wastewater. The end section of this inlet pipe was set on a small pad of concrete to prevent scarring of the bottom and slippage of the pipe down the long slope of the dike.

The discharge of the inlet is typically near the center of the lagoon to obtain mixing. When mechanical aeration is provided the inlet discharge should be in a zone of turbulence caused by the aeration. In aerobic lagoons where mixing is not desired, the inlet may be located far from the outlet and/or in the deepest portion of the pond. At the demonstration plant the 6-inch inlet pipe to the first aerobic pond was extended to discharge to the deepest portion of the pond (Figure 6). This deep discharge was designed to reduce odor emission, to contain the anaerobic zone under the aerobic zone, and to provide storage for settleable solids in the wastewater.

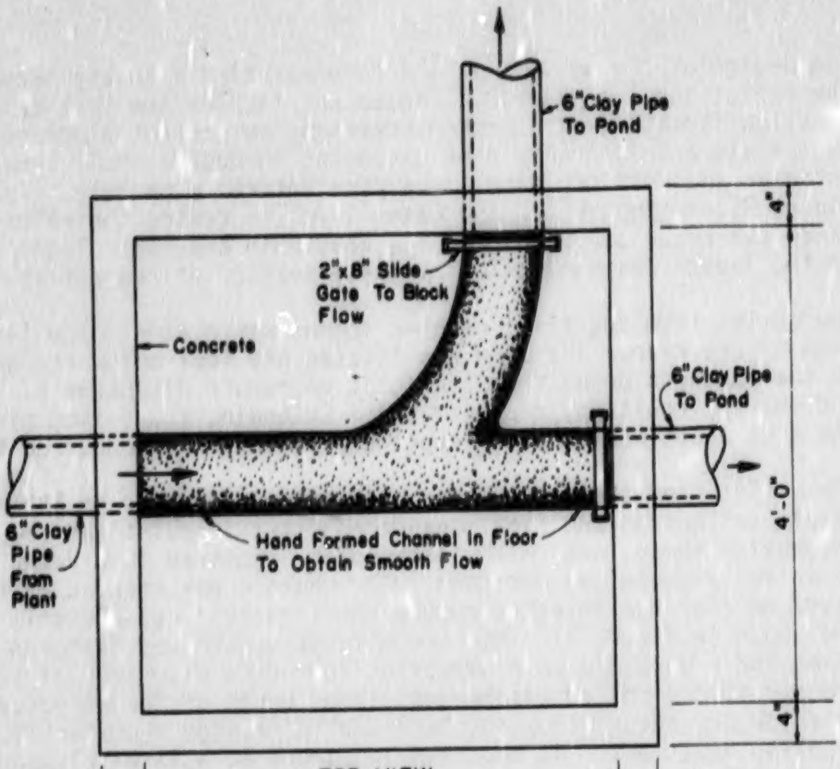
Control of the flow in the inlet design is needed to divert the flow around the lagoon during periods of repair and to divide the flow where two or more lagoons are used in parallel. Figure 7 is a detailed drawing of an inlet manhole used to by-pass the first lagoon at the Reeves plant. By use of a wooden gate in the manhole, flow can be diverted to the second lagoon. The square shape and other design details were to simplify construction.

Design of outlets requires the same considerations, i.e. capacity, elevation, location and control. The design of the outlet can incorporate several different desirable features depending on the lagoon process, i.e. scum retention, flow measurement, or restriction of the volume.

A second common outlet for lagoons is a drain which is located in the deepest portion of the lagoon. The drain pipe is designed to withstand the pressure of the dike and construction equipment and to accept a valve or plug. The pipe must have a water tight seal with the dike. The drain line can be eliminated if a large capacity pump, portable pipeline and power can be readily available to pump the lagoon.

The required outlet capacity is not necessarily the maximum gpm used in the plant. The lagoon will dampen the maximum flow to near the average used during the day's operation. Precipitation on surface of the lagoons will establish the maximum discharge possible. Usually this maximum discharge is not desired and is restricted by the outlet and use of the freeboard for temporary storage. The simplest of restrictions is the size of the outlet. Thus capacity, elevation and control in outlet design frequently interact to obtain a desired discharge volume.

The invert elevation of the outlet pipe controls the minimum water depth in the lagoon and must be set to obtain the desired depth. The outlet is located near to the next process or receiving waters to reduce pipeline cost and away from the inlet to reduce short circuiting.


6" Clay Pipe To Pond
4"
2"x8" Slide Gate To Block Flow
Concrete
6" Clay Pipe To Pond
4'-0"
6" Clay Pipe From Plant
Hand Formed Channel In Floor To Obtain Smooth Flow
4"

TOP VIEW

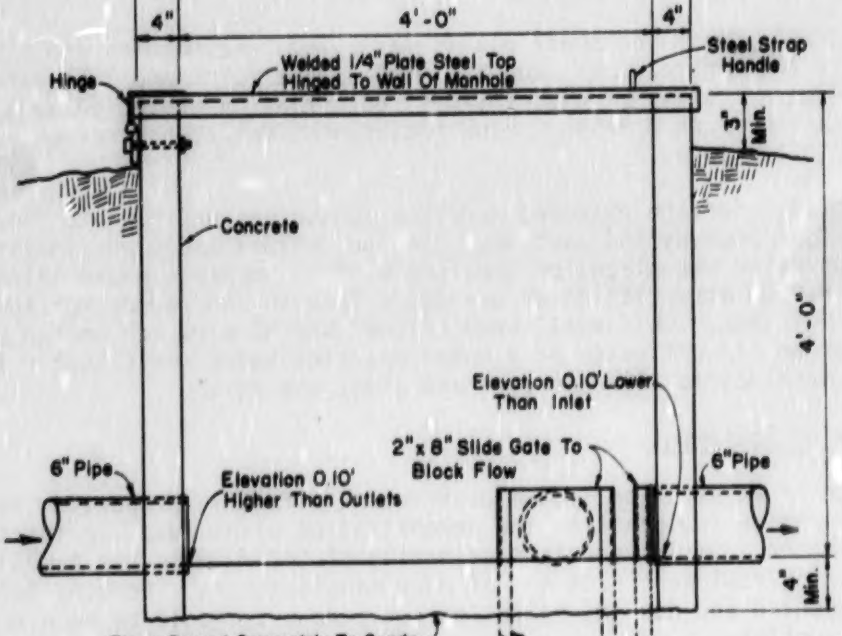

4"
4'-0"
4"
Welded 1/4" Plate Steel Top Hinged To Wall Of Manhole
Steel Strap Handle
Hinge
3" Min.
Concrete
4'-0"
Elevation 0.10' Lower Than Inlet
2"x8" Slide Gate To Block Flow
6" Pipe
Elevation 0.10' Higher Than Outlets
6" Pipe
4" Min.
Floor Poured Seperately To Grade
2" Channel Iron Driven Into Ground Concrete Poured Around

FIGURE 7 - INLET & BYPASS MANHOLE

The design of the outlets at the demonstration site are presented as examples. The outlet for the anaerobic lagoon was located two feet below the water surface to allow formation of a scum blanket and to prevent blockage of the pipe. The outlet was a 6-inch clay pipe extending through a small concrete pad on the interior slope of the dike. The pipe entered a manhole, similar to the one in Figure 7, one foot below the water level to reduce the release of odorous gases which can occur at overflow weirs used with anaerobic lagoons. The water level in the lagoon was controlled by the elevation of the outlet in the manhole.

The outlet from the first aerobic lagoon was a steel pipe laid during construction of the dike. The pipe was located one foot below the water surface and at the furthest point from the inlet to reduce discharge of floating materials and short circuiting, respectively. Extending the 6-inch pipe one foot beyond the dike slope would have prevented plugging which occurred twice.

The outlet from the second aerobic lagoon discharged to the receiving stream. Sample collection and flow measurement at this point was required. To accomplish these tasks with the accuracy required in a demonstration project an outlet manhole was designed. The manhole was located at the maximum distance from the inlet to reduce short circuiting. Details of the structure are shown in Figure 8. This concrete structure was designed with a submerged inlet and a variable weir elevation to reduce discharge of floating materials and permit controlled discharges. The length of the structure was designed to allow dry access from the bank and to provide room for flow measuring and sampling equipment. As depicted in Figure 8, a large plywood box was constructed and installed over the manhole to protect the composite sampler, flow recorder, and the sample container.

The NPDES permit for small plants may allow grab samples and flow measurements over a few minutes. If such is the case a simpler and less expensive design would be an outlet pipe at the desired elevation protected by a wooden baffle with a submerged opening. Flow measurement can be determined by the height of flow in the pipe.

The outlet for the extended aeration lagoon was designed to limit the discharge to a four hour period each day. The outlet was a 6-inch pipeline. An automated 6-inch valve was placed on the line within a manhole where maintenance could be performed. An accumulation of one day's flow in the lagoon raised the water level 6 to 9 inches. This small head allowed use of a rubber seated butterfly valve. Either an air activated or a motor operated valve was suitable in conjunction with an electric timer to open and close the valve.

Aeration Equipment

Design of an aeration system deserves an effort in proportion to its cost. The aeration equipment at the demonstration plant equalled the cost of constructing the lagoon. Design consists primarily of determining the needed capacity and selecting equipment from one of many manufacturers. Lengthy delivery times might be expected and design, selection and purchase should be done prior to starting construction.

The available equipment can be grouped into compressed aeration systems and mechanical aeration systems. The simplicity of installation and low initial cost

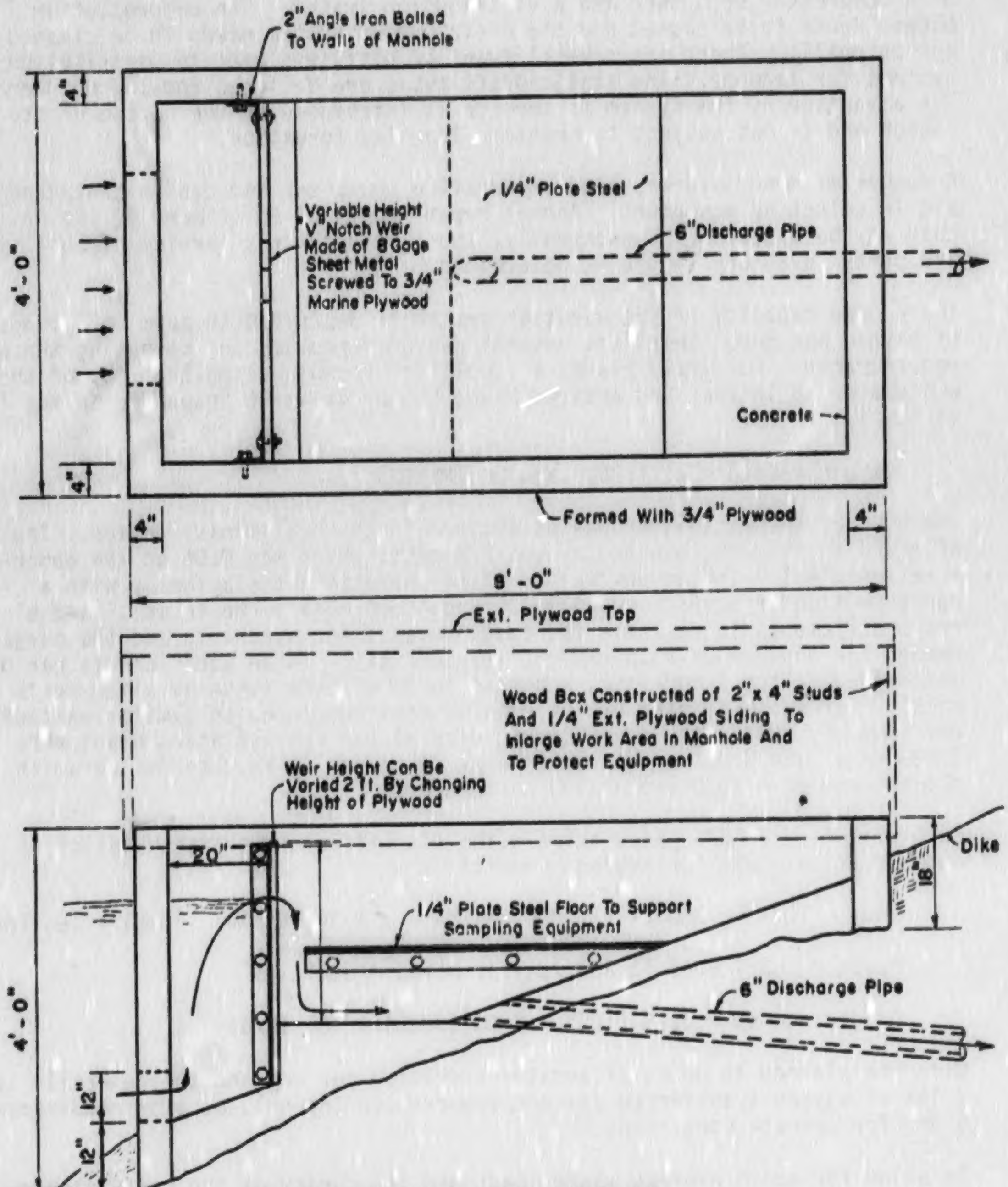

2" Angle Iron Bolted To Walls of Manhole
4"
1/4" Plate Steel
Variable Height V" Notch Weir Made of 8 Gage Sheet Metal Screwed To 3/4" Marine Plywood
6" Discharge Pipe
4'-0"
Concrete
4"
4"
Formed With 3/4" Plywood
4"
8'-0"
Ext. Plywood Top
Wood Box Constructed of 2" x 4" Studs And 1/4" Ext. Plywood Siding To Inlarge Work Area In Manhole And To Protect Equipment
Weir Height Can Be Varied 2 ft. By Changing Height of Plywood
20"
Dike
18"
1/4" Plate Steel Floor To Support Sampling Equipment
6" Discharge Pipe
4'-0"
12"
12"

FIGURE 8 - FINAL EFFLUENT MANHOLE

are advantages of the mechanical aeration systems which can be mounted on fixed or floating platforms. The changing water levels in the extended aeration lagoon eliminate fixed platform mechanical aerators. In climates where extensive ice formation is common, the floating aerator can malfunction due to ice build up on or around the equipment. The compressed air system consists of a compressor or blower and a distribution system. The compressor or blower needs to be housed and the distribution system needs to be cleaned occassionally. There are several types of diffusers used in distribution systems for lagoons. The static-draft tubes are designed for low maintenance. The advantage of the system is the air is introduced at the bottom of the lagoon and is not subject to problems from ice formation.

A number of manufacturers produce aeration equipment and can be contacted for aid in selecting equipment. Annual repair costs of 5% or more of the initial cost may be expected. Consequently, the manufacturer's service capabilities and parts inventory should be determined.

The needed capacity of the aeration system is described in terms of pounds of oxygen per day. There are several design formulaes for computing the oxygen requirements. For small plants a simplified formula using the BOD_5 of the wastewater in lbs/day and desired Mixed Liquor Volatile Suspended Solids (MLVSS) in lbs is:

$$\text{Oxygen Needed} = a' (BOD_5) \text{ and } b' (MLVSS)$$

The BOD_5 of the wastewater was determined in the preliminary design. The pounds of MLVSS is the BOD_5 divided by the F/M ratio which was 0.06 at the demonstration plant. The demonstration plant operated satisfactorily with a concentration of MLVSS between 1,000 and 4,000 mg/l. The terms a' and b' are coefficients to describe the oxygen needed for synthesis and the oxygen needed for endogenous respiration, respectively. These coefficients can be determined in the laboratory, and this is done where large aeration needs exist. For small plants, use of coefficients developed on similar wastewaters are commonly used. The coefficients used at the demonstration plant were 0.48 for a' and 0.03 for b', which were developed in an extended aeration plant treating a food processing wastewater.

Following is a sample calculation using the wastewater characteristics at the demonstration plant for average conditions:

$$BOD_5 = 1247 \text{ mg } BOD_5/\text{l } (17{,}800 \text{ gal/day}) \times 8.34 \frac{\text{lbs}}{\text{gal}} (10^{-6} \text{ l/mg}) = 185 \text{ lbs } BOD_5/\text{day}$$

$$MLVSS = 185 \div 0.06 \text{ lb } BOD_5/\text{day/lb } MLVSS = 3083 \text{ lbs}$$

$$\text{Oxygen needed} = 0.48 (185) + 0.03 (3083) = 181 \text{ lb/day}$$

With the planned 18 hours of aerator operation per day and the generally accepted 2 lbs of oxygen transferred per horsepower-hour (Hp-hr), aerator requirements were 5 Hp. for average conditions.

To allow for above average waste loads and inaccuracy of the coefficients, A 10 Hp. Peabody Welles floating aerator with a variable oxygen transfer valve was selected. This valve when open reduced the power consumption along with the oxygen transfer. The motor was equipped with a heater to keep it free from condensate moisture during the 6 hrs/day the aerator was off. The aerator supplied sufficient oxygen to operate the process even when operated at 8 Hp.

During the first 18 months the aerator ran as programmed except for a three-day inoperative period due to vandals cutting the mooring ropes. During the second 18 months, the aerator malfunctioned five times and was off for a total of two months. One malfunction was due to vandalism, three required rewinding the motor, and one was due to a problem in the electrical control panel. The motor was rewound twice due to poor alignment of the shaft and impeller when reassembling the aerator.

The amount of non-operation due to repair, and the infrequency of maximum oxygen requirements shows that dual aerators in the basin would have given superior performance. The aeration system, in addition to providing sufficient oxygen, must keep the biological floc mixed with the wastewater. Mechanical floating aerators have a conical shaped mixing zone, and two aerators would more effectively prevent sludge deposits in a rectangular basin. Thus selection of the aeration system and the F/M ratio may significantly affect lagoon design.

CONSTRUCTION

Construction begins with planning the sequence of events necessary to complete the facilities. This requires the coordination of equipment, manpower and materials for each event. Guidelines for satisfactory construction are presented under the subheadings of Preparation, Lagoons, Pipelines and Manholes, and General Items. Construction of the demonstration plant is described to indicate the planning required.

Preparation

The builder should determine the availability of transportation, handling, storage and disposal of materials; availability of labor, water, electric power, roads; and uncertainties of weather, river stages, or similar physical conditions at the site. He should determine the conformation and conditions of the ground, the character of equipment and facilities needed preliminary to and during the prosecution of the work and the character, quality, and quantity of surface and subsurface materials to be encountered.

The builder should be prepared to furnish all materials, equipment, tools, labor, supervision and other services necessary to construct a waste treatment system.

The builder should prepare for construction by clearing all timber, logs, brush, rubbish, large rocks and unsuitable soils from the lagoon site. Areas to receive fill or compaction should be scarified to a depth of six inches, and the moisture content of the material to be compacted should be adjusted to obtain near maximum density.

The builder will need to establish the center lines of principal structures, roads, pipelines, and facilities, set slope stakes and bench marks to establish the basic layout.

Lagoons

The lagoon should be excavated to the dimensions shown on the plans with special attention to maintaining the given inside and outside dike slopes.

Material for the fill is from the required excavation or designated borrow areas. The material used is to be free from vegetable matter and other deleterious substances and not contain rocks or lumps having a diameter larger than six inches.

The fill material is placed in uniform layers which when compacted shall not exceed six inches. Each layer shall be thoroughly mixed during the spreading to insure uniformity of material and moisture in each layer.

When fill material includes rocks, no large rocks should be allowed to nest and all voids should be carefully filled with earth, and properly compacted. No large rocks should be closer than twelve inches below the finish grade except on the inside slope of the dikes.

Compaction should be by sheepsfoot rollers, multiple-wheel pneumatic-timer rollers or other types of suitable compaction equipment. Compaction should be accomplished while the fill material is at a satisfactory moisture content. Compaction of each layer should be continuous over its entire area and the compaction equipment should make sufficient trips to insure that the desired density has been obtained.

Compacting equipment should be operated so that the full width of the fill is covered. Coverage shall be as one continuous trip from end-to-end and shall overlap previous coverage by not less than three inches. For pipelines laid in the fill, construct fill surface to at least an elevation two feet above the top of proposed pipeline prior to starting trench excavation for installation of pipelines. Sprinkle fill material with water as necessary to produce satisfactory compaction. If materials is too wet for proper compaction, aerate by discing. Upon completion, grade surface to proper elevations and cross sections. Dress side slopes as indicated.

The fill operation should be continued in six-inch compacted layers, as stated above, until the fill has been brought to the finished elevations.

All excess excavation, not required or suitable for backfill or filling, shall be disposed of in the designated waste area. The waste area shall be uniformly graded to conform to existing contours, left with a neat appearance, and be free-draining.

After grading is completed, topsoil should be spread over the entire graded area, excluding surfaced area covered with gravel or rip rap and surface areas to be inundated by water, and planted with native grass.

Pipelines and Manholes

Clay pipe where used should be standard strength clay sewer pipe and conform to American Society for Testing and Materials (ASTM) standards. When pipe is being placed the lower 90 degree arc of the barrel of the pipe should be in firm contact with undisturbed earth. Excavations should be made for the bells, but should be no larger than necessary to clear the bell. Where clay pipe is to be laid on rock or where the surface is unsmooth and irregular a four inch layer of sand, crushed rock or small aggregate should be placed under pipe for complete support. Clay pipe should be laid with correct alignment and slope. Joints must be watertight to hold infiltration to a minimum. Trenches should be kept water-free during jointing and for a sufficient period thereafter to allow the jointing material to become fully set and completely resistant to water penetration.

Obstructions to the construction of the trench, such as tree roots, stumps, abandoned structures, and debris of all types, should be removed. Minimum width of trenches in which pipe is to be laid should be 18 inches. The alignment and grade of the trench should be established by a surveying instrument with proper allowance for pipe thickness and for base or special bedding when required. Removal of rock from the trench and the equipment and grade boards used at the demonstration plant are shown in Figure 9.

Where pipes pass through the embankments, no granular pipe base or pipe zone material should be used. Instead, the pipe should be laid on the trench invert. Steel pipe joints should be welded. The trench should be backfilled with selected material.

If the manhole is cast-in-place the form's exterior exposed surfaces should be plywood. Form all vertical surfaces. Trench walls, large rock or earth is not a suitable form material. The concrete should be a high strength mix.

Precast manhole sections conforming to ASTM Standards, with circular reinforcement, may be used. The diameter at the base should not be less than four feet.

The concrete base should be constructed so that first section of precast manhole has uniform bearing throughout the full circumference. Sufficient grout should be deposited on base to assure watertight seal between base and manhole wall or the precase section of manhole can be placed in concrete base before the concrete has set. The section should be properly located and plumbed. If material in bottom of excavation is unsuitable for supporting a manhole, excavate two additional feet and backfill to required grade with three inch minus, clean, pit-run material. Water should be removed from the excavation prior to pouring the base.

Do not backfill around concrete structures until the concrete has obtained sufficient compressive strength. Remove all form materials and trash from the excavation before placing any backfill.

Do not operate any heavy earth-moving equipment within 5 feet of walls of concrete structures for the purposes of depositing or compacting backfill material. Compact backfill adjacent to concrete walls with pneumatic tampers or other equipment that will not damage the structure.

General Items

The builder should surround the waste treatment site with a permanent stock-tight fence and provide appropriate signs to designate the nature of the facilities.

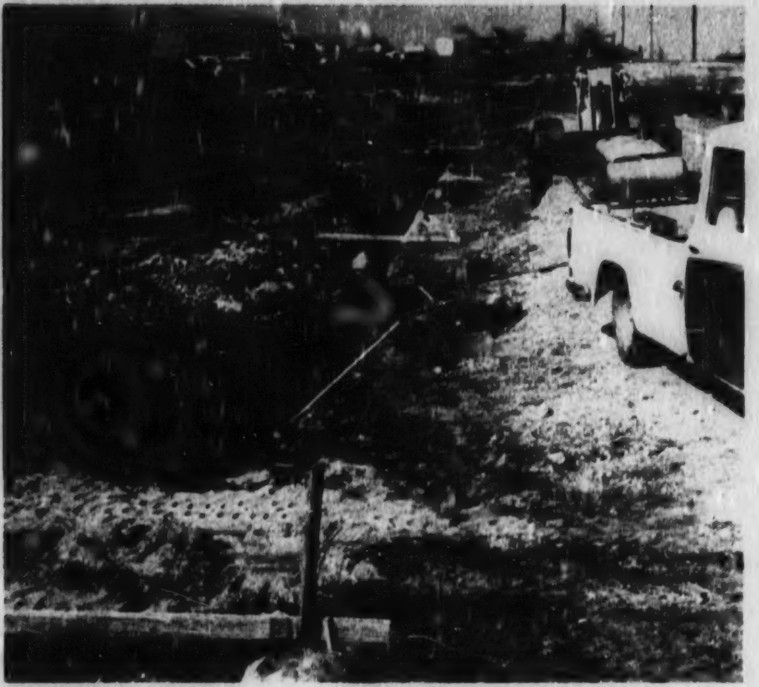


FIGURE 9 - TRENCH CONSTRUCTION FOR SEWERLINE

FIGURE 10 - MOWING GRASS AROUND LAGOONS

The builder should take necessary precautions for the safety of employees on the work site and to prevent accidents or injury to persons on, about, or adjacent to the premises where the work is being performed. The builder should provide and maintain at all times during the progress or temporary suspensions of the work, suitable barricades, fences, signs, signal lights, and flagmen as necessary to insure the safety of the public and those engaged in the work.

The builder should construct the necessary ditches, provide the necessary pumps, and take such precautions as are required to protect the work. Divert or pump and streamflow and drain the construction area so the work may be carried on in a satisfactory manner. Drain or otherwise dewater all excavation areas as required to permit satisfactory operation.

The builder should construct an access road to the work site during construction suitable for latter access by operators.

The builder should keep the property on which work is in progress and the adjacent property free from accumulations of waste material or rubbish caused by employees or by the work.

Demonstration Plant

Construction of the demonstration plant shown in Figure 4 was begun in December and required four months to complete the pipelines, manholes, and three ponds. The anaerobic pond and sewer were completed first and wastewater was turned into the pond on February 1. The two aerobic ponds were completed next and received wastewater on April 15. The fence and auxiliary items were then installed. The last construction item was sprigging of the dikes with bermuda grass which was delayed until just prior to the growing season.

Weather, diversion of manpower to other tasks and slow delivery of mechanical equipment were the causes of the major construction delays. Construction equipment breakdowns and availability of construction materials were minor problems.

Construction of facilities shown in Figure 4 was mainly accomplished by three maintenance personnel at the packinghouse under the direction of the owner. Two others aided in operating dump trucks, front-end loader, and bulldozers during the earth moving phases of construction. Other part-time manpower consisted of a survey party and an engineer. No other manpower was required except that used by the electric company to relocate power pole and to install service to the project. The use of packinghouse personnel resulted in delays in construction but minimized cash outlays.

The equipment used on construction of the facilities consisted of two bulldozers, one 16-yard earthmover, three dump trucks (1-12 yard and 2-6 yard), one backhoe, one front-end loader, one pickup truck, two air compressors, and a 1/2 sack concrete mixer. The earthmover was inoperable for several weeks and most of the soil was transported by the trucks. The owner purchased some of the equipment and leased the rest.

The major materials purchased were soil (a silty clay loam), vitrified clay sewer pipe, steel pipe for drains, cement, gravel and sand for concrete, form lumber and dynamite.

OPERATION

Preliminary design, funding, detail design and construction are only undertaken so the treatment system can be operated. Operation need not be difficult or time consuming, but it must be daily. For small plants, a daily inspection to catch malfunctions early is the most important part of operation. Something as simple as seeing an abnormal discharge volume or water height will allow correction before a major problem occurs. The first and most important part of operation is to assign responsibility for the system to a capable and conscientious employee.

After an operator has been selected and his work schedule arranged to permit daily inspection and operation, he should be instructed to compile the available information and tools to also undertake maintenance. All manufacturer's specifications, shop drawings and maintenance manuals should be read and kept as a permanent record. A manual on operation of treatment plants should be obtained and used as a reference. Operation of Wastewater Treatment Plants, Manual of Practice No. 11, is available from the Water Pollution Control Federation, 3900 Wisconsin Ave., Washington, DC 20016 for $3.00. This manual contains information on the causes and cures of many operational problems. Those reports listed in the appendix of this publication will give further information on operation and maintenance of specific wastewater treatment systems.

Care of the treatment site is also necessary. The fences, gates and access road will need to be maintained. Mowing of the grass in the land intensive system as described herein can be quite time consuming. A simple but effective alternate is to have cattle graze the grass and occassionally mow the weeds and brush as is done in most pastures (Figure 10).

Other than the necessary daily inspection the amount of operation and maintenance will vary considerably depending upon the amount of mechanical equipment, season of the year and detail design. A system of routine preventative maintenance should be developed especially for mechanical equipment. Some of the routine maintenance that can be expected by type of facility follows:

> Pipeline and manholes will need cleaning of grit, grease, and plant growth to prevent plugging and odors.
>
> Pumping stations will have similar cleaning requirements and the pumps will need to be lubricated and the packing gland checked. The motors, belt drives and water level control will need adjustments. The pumps used should be alternated weekly.
>
> Screening facilities and grease traps need to be inspected daily and cleaned when required to obtain effective solids-liquid separation. The collected solids can be disposed of by burying.
>
> Chlorination facilities need to be checked daily to determine feed rates, availability of chlorine and leaks.
>
> The extended aerated lagoon has an aeration system, an automated control panel, and a power operated valve. Daily inspection is necessary to determine satisfactory operation. Collecting a sample of mixed liquor and determining the solid-liquid separation in 30 minutes will show if excess sludge is being carried out with the

discharge. The extended aeration lagoon needs to have sludge withdrawn when the MLSS concentration goes above 5000 mg/l. These settling and concentration measurements on the mixed liquor indicates one use of an analytical monitoring program for operation. A monitoring program especially designed for small packers and the use of this information will be given by Rowe later in this publication.

The sludge from an extended aeration process has been highly treated and if disposed on land can be a simple operation for small plants. On five occasions during the year at the demonstration plant several thousand gallons of settled sludge were removed through the drain pipe and placed in the surrounding pasture.

A plant manager may wish to establish a maintenance and operation form to remind the employee of daily, weekly and monthly inspection, maintenance, and monitoring duties and to establish a record of diligent operation. A form that covers one months activities has been found most convenient.

LIST OF ABBREVIATIONS AND SYMBOLS

BAT	Best Available Technology Economically Available
BOD_5	Five day Biochemical Oxygen Demand
BPT	Best Practical Control Technology Currently Available
COD	Chemical Oxygen Demand
F/M	Food to Microorganism Ratio
FOG	Fats, Oils or Greases
gal/day	gallons per day
gpm	gallons per minute
Hp-hr	Horsepower-hour
LWK	Live Weight Killed
mgad	million gallons per acre per day
mgd	million gallons per day
mg/l	milligram per liter
ml	milliliter
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
mm	millimeter
mpn/100 ml	most probable number per 100 milliliters
n	number
N_2	Nitrogen as a gas
NH_3	Ammonia
NH_3-N	Ammonia as Nitrogen
NO_2^-	Nitrite
NO_3^-	Nitrate
NPDES	National Pollutant Discharge Elimination System
SRT	Sludge Retention Time
SVI	Sludge Volume Index
TKN	Total Kjeldhal Nitrogen
T-P	Total Phosphate
TSS	Total Suspended Solids

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EVALUATING AND TREATING POULTRY PROCESSING WASTEWATER

W. K. Whitehead

INTRODUCTION

The U.S. poultry processing industry slaughters over 3 billion chickens annually (1) and produces a tremendous amount of waste that must be treated before it can be released to a stream. Waste treatment represents an ever increasing cost to both processors and consumers. Recent performance standards (2) and other regulations require that the wastes be sufficiently treated to reduce pollution effects on our environment.

The quantity of water used for processing poultry and the amounts of wastes generated in the processing areas have been reported. Data from the Gold Kist Study (3) showed that the average water use for a typical processing plant was 46.5 liter/bird or about 28 liter/kg LWK (live weight killed). As recently as 1971 poultry processing plants in Georgia were using an average of 40.5 liter/bird for slaughter, eviscerating and further processing (4) and for plants with a municipal water supply the average water rate was $0.12/m^3. Based on these data, water costs the poultry processing industry about $14 million annually or about $4.86 per thousand chickens slaughtered.

One recent study (5) reported average raw waste characteristics for chicken processors. BOD_5 averaged 9.9 kg/k kg LWK; suspended solids, 6.9 kg/k kg LWK; grease, 4.2 kg/k kg LWK; and COD, 19.7 kg/k kg LWK. This study also reported that the principal sources of waste water in the plants surveyed were the feather and offal flow away systems, but other areas also contribute to the waste load. Hamm (6) reported that the bird chiller, giblet chiller, eviscerating and scalder-defeathering areas produced significant amounts of COD, fat and solids. Carawan *et al* (3) reported that over 51% of the total BOD_5 load originated either in the blood collection tunnel, clean-up operations, or in other miscellaneous activities. That report showed that the final bird washer and the giblet and bird chillers accounted for about 1.5 kg BOD_5/k kg LWK. Drainage from the offal truck was another large contributor. The overall plant average BOD_5 load was 15.72 kg/k kg LWK.

If poultry processors are to meet recent regulations governing the amounts of wastes they may discharge to natural streams, investments of time and money must be extended. The performance standards (2) eventually limit discharges to 0.30 kg BOD_5/k kg of LWK, 0.34 kg TSS/k kg of LWK, 0.20 kg oil and grease/k kg

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Agricultural engineer, Richard B. Russell Agricultural Research Center, Southern Region, Agricultural Research Service, U.S. Department of Agriculture, P. O. Box 5677, Athens, Georgia 30604.

of LWK and 4.0 mg of ammonia/liter of effluent. Compliance with those levels is not impossible, but most poultry processing waste treatment systems do not consistently meet those standards. One recent analysis (7) estimated investment and operating costs for model processing plants. A large broiler plant with a capacity of 76,800 birds/day and a wastewater volume of 2700 m^3/day would require an incremental investment cost of $161,000 and an annual operating cost of $25,000 to meet the 1977 best practicable technology currently available (BPT) treatment level. This same plant would require an investment of $203,000 and an annual operating cost of $52,000 to achieve the 1983 best available technology economically achievable (BAT) guidelines. An investment of $578,000 and $62,000 annual operating cost would be necessary to meet the new source performance standards (NSPS).

Several alternatives are available for treating poultry processing wastewater. Pretreatment with screens, filters and/or flotation is necessary before discharging the wastewater to either a municipal or private waste treatment system. These procedures can reduce BOD_5 and concentrations of suspended solids and fat by removing the larger solids from the wastewater. About 65% of the Federally inspected poultry processing plants discharge their final waste to a municipal treatment system (8). This may be the most economical means of handling the wastewater, but for the remaining 35% not having access to municipal sewers an efficient private waste treatment system is necessary to comply with the discharge standards.

Most plants with private waste treatment systems utilize some form of lagoon, either anaerobic, aerobic or a combination of types. Extended aeration, land application, the rotating biological contactor and activated sludge may also be used. However, in 1972, Vertrees (8) reported that only two poultry processing plants used activated sludge and therefore, little information is available on the application of activated sludge to poultry processing wastewaters.

Since its conception, the activated sludge process has been widely used for treatment of both municipal and industrial wastewaters. Various modifications of the process have been developed, but some basic principles are common to all the processes. The conventional activated sludge process can remove 95% of the BOD_5 and suspended solids. Although the process produces solids that must be disposed of, it is very stable and reliable and, when compared to the alternatives of lagoon or land application systems, its greatest advantage is the small land area required.

The major physical structures of an activated sludge process are the biological reactor and the solids-liquid separator. The inputs to the reactor are wastewater and concentrated activated sludge from the separator and air. Microorganisms in the return sludge react with the organic pollutants in the wastewater to produce more activated sludge, carbon dioxide and water. The supplied air provides a mixing action and oxygen for the reaction. The process effluent is the clarified overflow from solids-liquid separator. The net production of sludge must be withdrawn and further processed or dryed for disposal.

The objectives of this study were to: (1) identify areas of waste generation in a poultry processing plant and characterize and quantify the amounts of waste produced, (2) monitor an existing lagoon-type waste treatment system and determine its efficiency for treating poultry processing wastes, and (3) design a laboratory-scale conventional activated sludge system and operate it under controlled conditions to determine its feasibility for use to treat poultry processing wastewater and determine optimum operating conditions.

PROCEDURE

The first phase of this project was to identify the amounts of waste produced in each area of a poultry processing plant. A survey of commercial processing plants showed that several areas seemed to be major contributors of waste, the scalding process, the picking area, the eviscerating room and the chillers. The wastewater from one plant, processing 9600 broilers per hour, was sampled and analyzed for a period of about 10 weeks. Samples were collected weekly, during normal plant operations, from the scalder overflow, the eviscerating troughs, the whole-bird chillers, the giblet chillers, the offal truck discharge and the total plant final effluent. Samples were analyzed for BOD_5, COD, TOC, fat, total and volatile solids, and total and volatile suspended solids (9).

The total amount of water used in the processing plant was recorded and the amounts used in certain areas were measured. The amounts of overflow from the scalders and the chillers were fixed by inspection regulations at 0.95 and 1.9 liter per bird, respectively. The total amount of water used in the eviscerating room was that measured with a 90°V-notch weir plus the amount used in hand-wash stations, which was calculated by collecting and timing the discharge.

In the second phase of the project, we monitored an existing poultry processing plant waste treatment system. This system (Fig. 1) is a four-stage lagoon process with aeration in the first two ponds. The first pond has a surface area of 14,600 m^2 (3.6 acres) and is equipped with three aerators. Discharge from this pond flows to a second pond with 1080 m^2 (0.27 acres) surface area equipped with one aerator which keeps the wastewater in a highly mixed condition. The wastewater then flows to the first of two settling ponds. Neither of these ponds is aerated or mixed. Surface area of the first is 8820 m^2 (2.2 acres) and of the second, 7130 m^2 (1.8 acres). The effluent from the final pond is discharged through a weir to a small stream.

The plant processed about 90,000 broilers/day, 5 days a week during the sampling period. The amount of water discharged to the stream was measured by the weir, recorded continuously and averaged about 13,225 m^3 (3,500,000 gal) per week.

Grab samples taken while the plant was operating and 24-hour composite samples of the raw wastewater and the treated effluent were collected weekly for 18 weeks during the summer and early fall. Samples were collected on Wednesday or Thursday of each week and analyzed for BOD_5, COD, TOC, fat, total and volatile solids, total and volatile suspended solids and total (Kjeldahl) nitrogen (9).

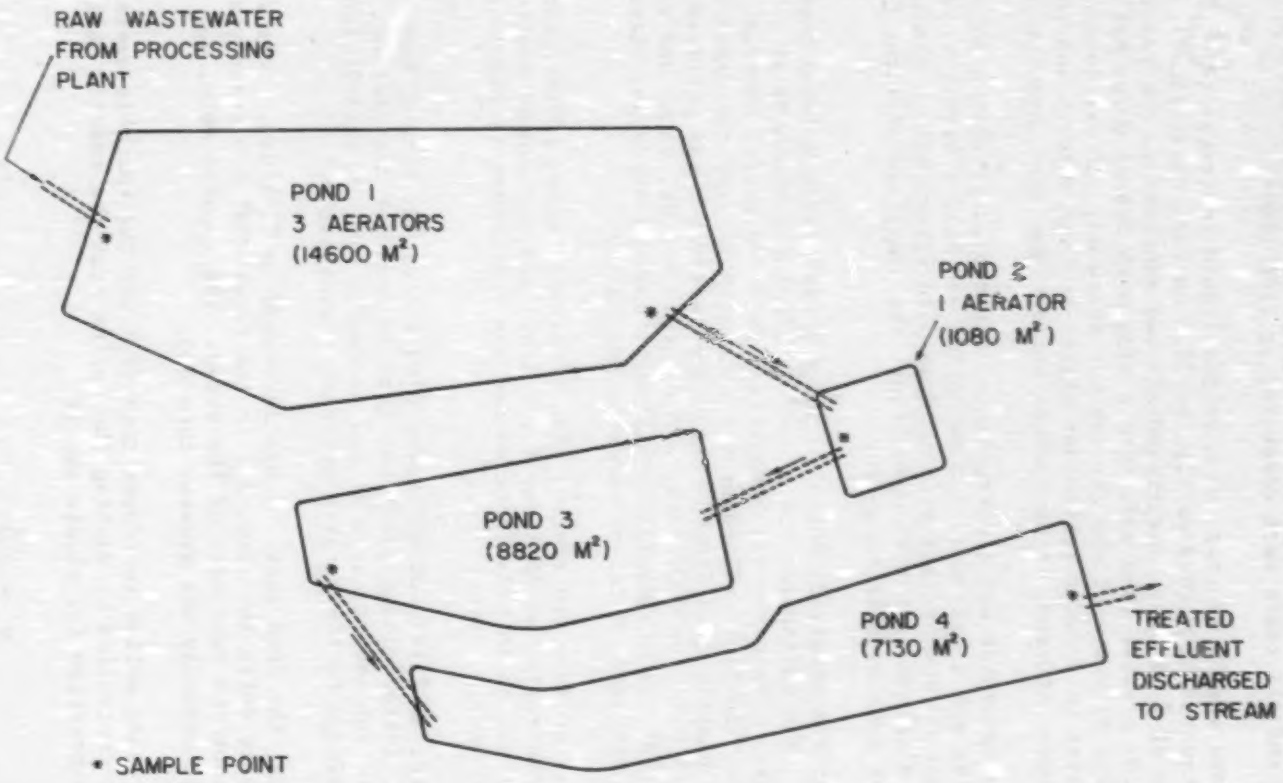
RAW WASTEWATER
FROM PROCESSING
PLANT
POND 1
3 AERATORS
(14600 M^2)
POND 2
1 AERATOR
(1080 M^2)
POND 3
(8820 M^2)
POND 4
(7130 M^2)
TREATED
EFFLUENT
DISCHARGED
TO STREAM
* SAMPLE POINT

Fig. 1 Layout of a poultry processing plant's stabilization ponds.

To determine if activated sludge is a feasible process for high strength poultry processing wastewaters, we operated a lab-scale activated sludge unit under controlled conditions for several months. The system was located in a controlled environment room and all tests were conducted at 21°C (70°F).

The main components were a reactor and a solids-liquid separator (Fig. 2). The reactor was constructed of a 20.3 cm I.D. by 35.6 cm long clear plastic tube and held a volume of 7 liters. Compressed air was supplied to the reactor through a 7 mm I.D. plastic tube made into a ring with 0.8 mm holes drilled on 13 mm centers. The flowrate of the air was not measured, but was controlled by a pressure regulator to provide sufficient oxygen for the reactor and to help keep the mixed liquor stirred. A mechanical stirrer was also used for agitation.

The solids-liquid separator was constructed of clear plastic with a 30.5 cm by 30.5 cm top opening and a 3.2 cm by 3.2 cm bottom and held a liquid volume of 17 liters. The bottom was drilled with a 13 mm hole fitted with a plastic tubing that served as the solids recycle line. The clarified effluent flowed from the separator into a collection tank.

The raw wastewater was obtained, normally twice a week, from a local commercial processing plant. The wastewater was stored in plastic containers at 2-3°C until ready for use. The water was homogenized in a commercial blender, then placed in glass feed bottles. Blending was necessary to keep the waste from fouling the small plastic feed lines. Each time wastewater was obtained, it was sampled and analyzed for COD, total and volatile solids, total and volatile suspended solids, fat, total (Kjeldahl) nitrogen, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total phosphorous and pH (9).

Raw wastewater was fed into the reactor with a variable speed peristaltic pump. The flowrate was controlled at 28 l/day (1.17 l/hr) and was pumped continuously. The feed water was stored in glass bottles and was maintained at 2-3°C by a refrigerated-water bath.

On initial start-up, 20 liters of activated sludge from the return line of a 3 MGD municipal activated sludge plant was used as seed for the reactor. The system was operated for several days at low hydraulic flow rate (6-10 l/day) to acclimate the sludge to the poultry processing wastewater.

After about 3 weeks, the feed rate, Q, was increased to 28 l/day. This feed rate gave a hydraulic detention time, θ_H, in the reactor of 6 hrs and was maintained throughout the remainder of the study. The recycle rate, Q_R, was not controlled, but normally was greater than 4 Q.

The sludge age, or mean solids residence time (θ_S) was the variable operating parameter, and was controlled by wasting the solids from the reactor daily. The mathematical expression for sludge age is

$$\theta_s = \frac{VX}{Q_W X_R} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (I)$$

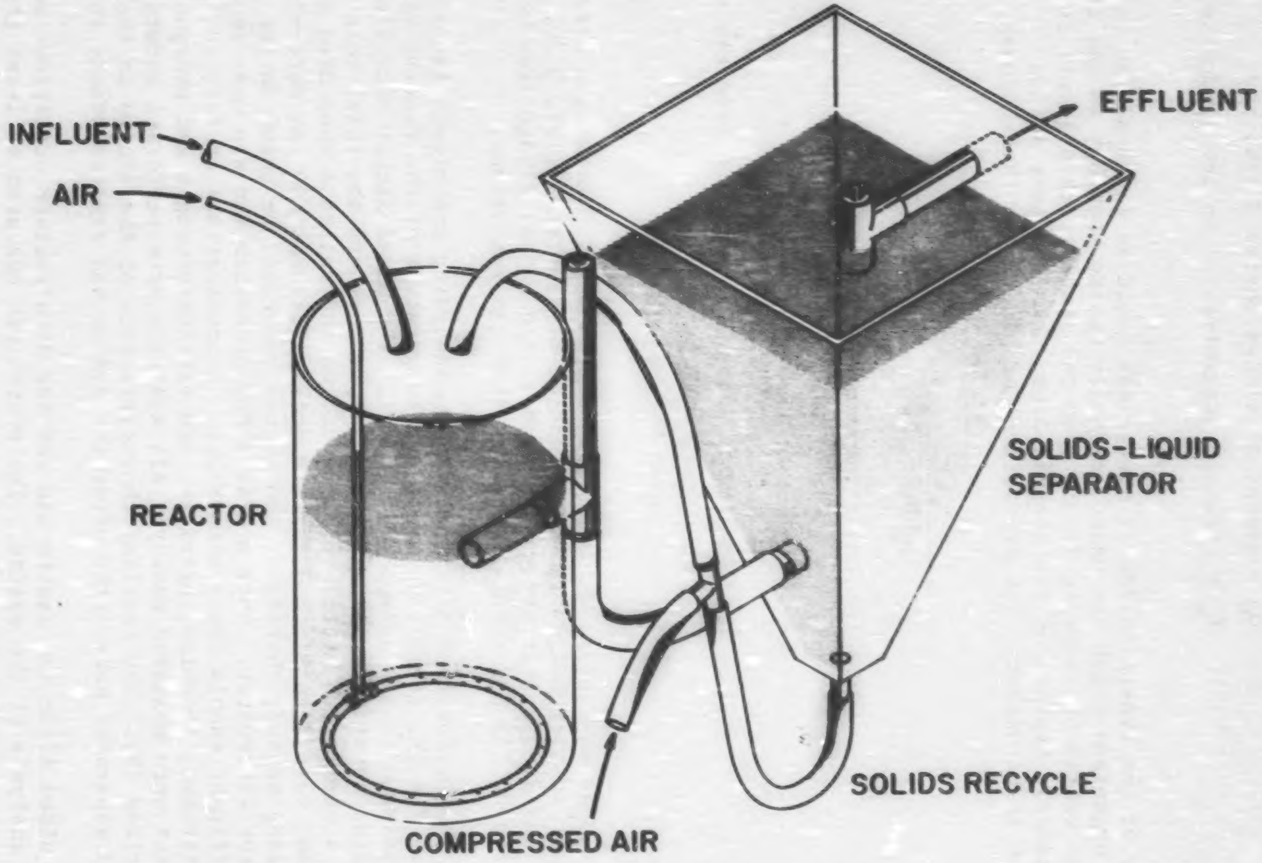
INFLUENT
AIR
EFFLUENT
REACTOR
SOLIDS-LIQUID SEPARATOR
SOLIDS RECYCLE
COMPRESSED AIR

Figure 2. Laboratory-scale activated sludge unit.

where:

V = volume of the reactor
X = organism concentration in the reactor,
Q_W = amount of sludge wasted daily, and
X_R = organism concentration in the sludge recycle.

The accuracy of the determination of sludge age could be increased by including the mass of organisms which are unintentionally wasted each day in the effluent. If solids are wasted by removing liquid from the reactor (this liquid is called the mixed liquor), instead of the recycle line, then one less solids determination is necessary. The expression for sludge age then becomes

$$\theta_S = \frac{VX}{Q_W X + (Q - Q_W) X_E} \; . \; . \; . \; . \; . \; . \; . \; (II)$$

where:

V = volume of the reactor,
X = MLVSS, mg/l,
Q_W = amount of sludge wasted daily from the reactor,
Q = hydraulic flow rate,
X_E = effluent VSS, mg/l.

We selected sludge ages of 1, 2, 3.5, 7, 10 and 14 days. These ages were accomplished by wasting solids from the reactor at the rates 1.0V, 0.5V, 0.29V, 0.14V, 0.10V and 0.07V, respectively. However, the actual sludge ages were calculated with Eq. II and were always less than the set values.

We evaluated the performance of the system by analyzing the mixed liquor and the effluent. The pH, dissolved oxygen and temperature of the reactor mixed liquor were measured daily except on weekends. The mixed liquor volatile suspended solids were determined three times per week and the total volatile solids, once a week. COD, total volatile solids and volatile suspended solids of the effluent were determined 3 times a week. Effluent COD was determined on filtered samples and, therefore, the values reported are based on the soluble material in the wastewater. Once a week a COD determination was made on an unfiltered effluent sample for a comparison. Concentrations of fat, total (Kjeldahl) nitrogen, ammonia-, nitrite-, and nitrate-nitrogen and phosphorous in the effluent were measured weekly. All analyses were performed according to current practices (9). The settling characteristics of the sludge in the solids-liquid separator were noted after the system had reached steady state.

Only data acquired after the system had reached steady-state conditions were used for the analysis of the system. The system was operated at least three times the set sludge age before any steady-state data were taken. However, this was not the only requirement for determining steady state. The system was determined to be in a steady-state condition when the concentration of the mixed liquor volatile suspended solids and the calculated sludge age became relatively constant from day-to-day; uniformity of the settling properties of the sludge in the solids-liquid separator also was a good indicator.

RESULTS AND DISCUSSION

Waterflow measurements showed that the eviscerating room area accounted for 26% of the total plant water use and about 33% of the process water. Analysis of the wastewater indicated that the eviscerating room was responsible for 37% of the total plant BOD_5, 42% of the COD, 32% of the suspended solids and 90% of the fat (Table 1). Since many processing plants have problems with fat in their effluent, these data indicate that the eviscerating room is the major contributor and special attention should be given to the processes in this area to reduce the fat load in the water. Any process modification that reduces the amount of fat entering the water will also reduce the BOD_5, COD and suspended solids concentration.

The scalder and whole-bird chiller were regulated at 0.95 and 1.9 l/bird, respectively, which combined accounted for about 7% of the total plant water use and about 9% of the process water use. The combined wastes from these two areas accounted for about 9% of the total BOD_5, COD, suspended solids and fat. The amounts of water are fixed and little, if anything, can be done to reduce the wastes generated in these areas. However, one allowable solution is reuse of the discarded chiller water in the scalder. This may not be economically feasible because of the cost of heating the chilled water and because these areas combined account for only 9% of the total waste; efforts to reduce the pollution load probably could be more profitable elsewhere.

The offal truck discharge, with a flow of only about 35 l/min, was highly concentrated and was responsible for about 5% of the total BOD_5 and COD, 2% of the suspended solids and nearly 3% of the fat. These data indicate that the liquid waste portion of the offal on the truck or receiver should be contained so that it is not released into the water. In addition, tanks could be mounted on the offal truck to receive the blood. If pneumatic waste handling systems are used and excess water were excluded, the offal truck could be eliminated as a source of pollution.

The data from monitoring a processing plant's lagoon treatment system are summarized in Table 2 and Figures 3 and 4. The average concentrations of the wastes in the effluent from these stabilization ponds were: BOD_5, 18 mg/l; COD, 103 mg/l; suspended solids, 40 mg/l; and fat, 6 mg/l. Based on kg BOD_5/k kg of LWK (kg per 1000 kg of live weight killed) the mean BOD_5 during the sampling period was less than the BPT (best practicable control technology currently available) average in the EPA proposed performance standards for poultry processing products. The mean BOD_5 exceeded the BAT (best available technology economically achievable) average and the high BOD_5 value equalled the BAT maximum.

Table 1. Summary Of Data[1] For Raw Wastes From One Commercial Poultry Processing Plant

Area	BOD_5 mg/1	COD mg/1	TOC mg/1	Total Solids mg/1	Total Suspended Solids mg/1	Volatile Suspended Solids mg/1	Fat mg/1
Eviscerating Room	1522	2389	262	1047	430	423	962
Whole Bird Chiller	830	1175	175	933	365	361	335
Giblet Chiller	1251	1570	269	1216	236	234	170
Scalder	1044	1678	396	1843	216	208	68
Offal Truck	7050	12052	2231	8223	1286	1260	1433
Final Effluent	1116	1691	216	999	368	362	266

[1] Values are averages of 6 weekly determinations.

Table 2. Summary Of Data From A Commercial Poultry Processing Plant's Lagoon Waste Treatment System

	BOD_5		COD		Suspended Solids		Fat	
	mg/1	kg/kkgLWK[2/]	mg/1	kg/kkgLWK	mg/1	kg/kkgLWK	mg/1	kg/kkgLWK
Mean [1/]	18	0.32	103	1.80	40	0.69	6	0.10
Low	10	.18	72	1.26	4	.07	4	.07
High	34	.60	160	2.80	94	1.65	10	.18

[1/] Values are means of 18 determinations.

[2/] Values are based on 0.7 MGD discharge and 90,000 broilers processed per day.

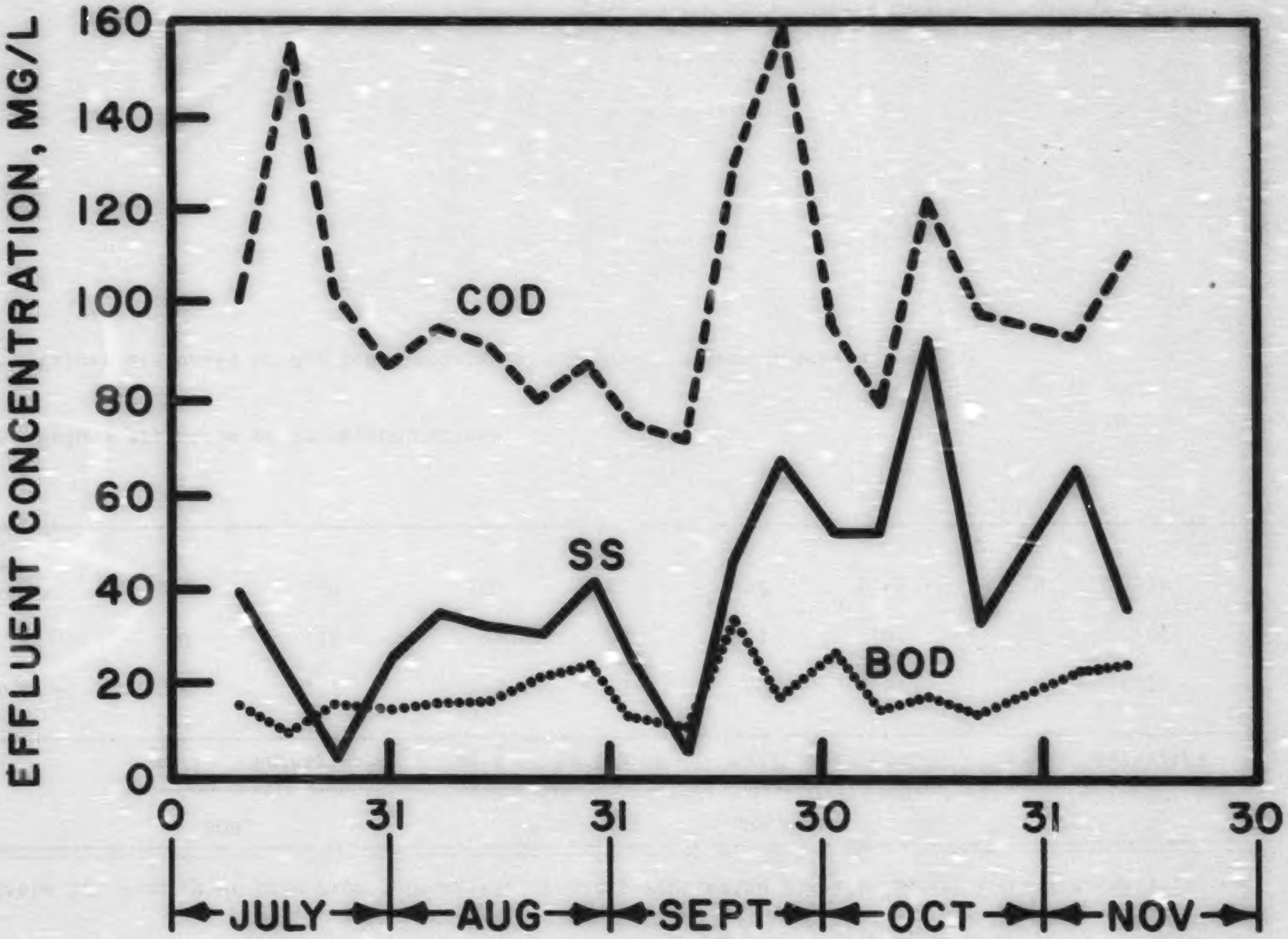

Fig. 3 BOD$_5$, COD and total suspended solids effluent concentrations from a commercial poultry processing plant's stabilization ponds.

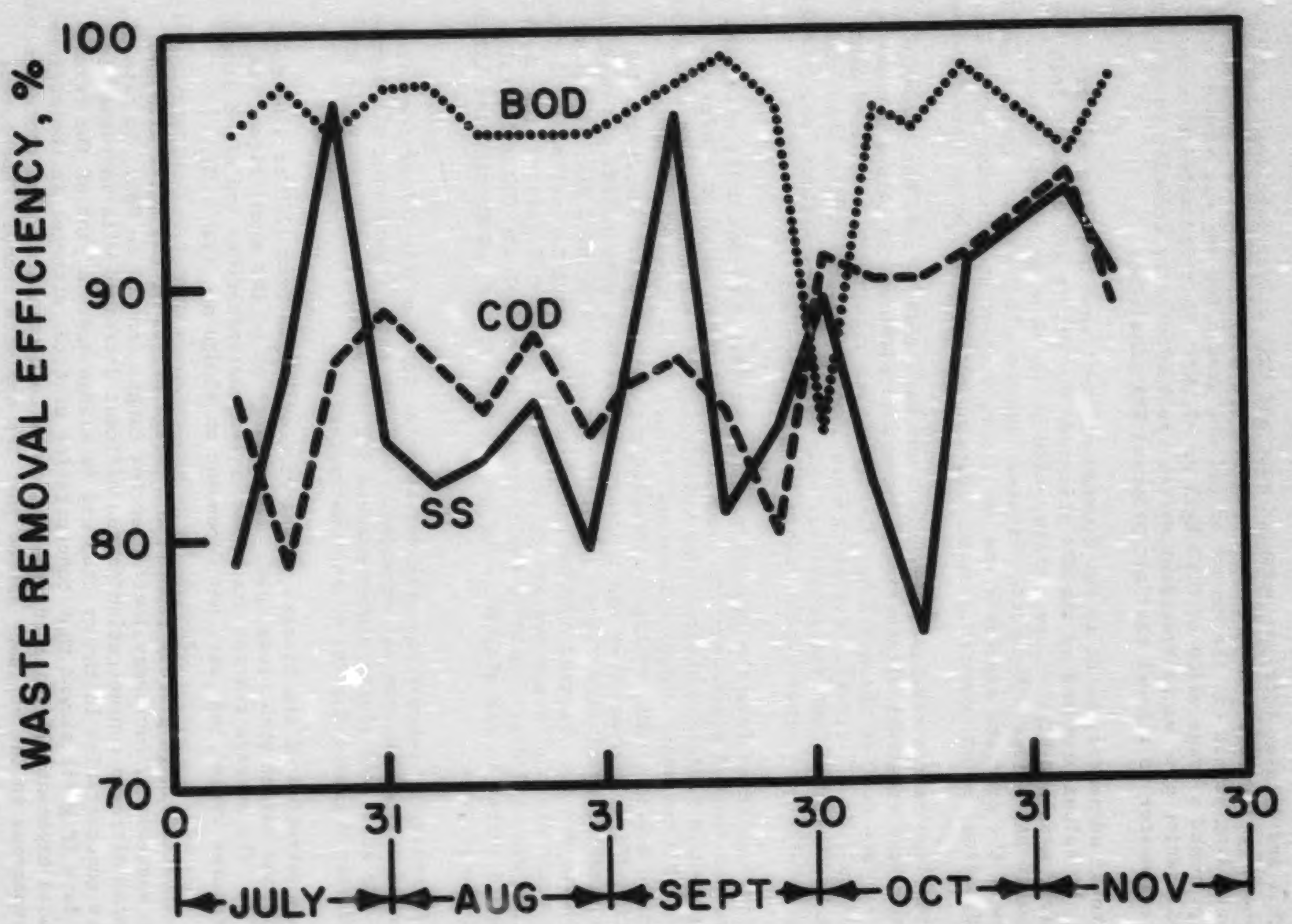

Fig. 4 Waste removal efficiency of a commercial poultry processing plant's stabilization ponds.

For oil and grease, both the measured mean and high values were less than the proposed performance standards for both BPT and BAT. In fact, at no time during the sampling period did the amount of oil and grease for any one sample exceed the proposed average value of 0.20 kg/k kg of LWK. This indicates that the stabilization pond waste treatment system was biologically reducing the fat in the wastewater to a level that met proposed EPA standards.

The total suspended solids in the treated effluent were significantly greater than the values proposed by the EPA standards for either BPT or BAT. Both the measured mean and high values for suspended solids were more than twice the allowable BAT values. Apparently aerated lagoon waste treatment systems would not meet the proposed standards and would not, without an extensive amount of modification, be an acceptable waste treatment alternative for poultry processors.

Aerated lagoons are relatively efficient and maintenance free, but probably are not the best treatment alternative. The system monitored in this study had a pond surface area of about 3.2 ha (7.9 acres) and required a total land area of more than 6 ha (15 acres). For processors located in rural areas, this land might be available, but for facilities near an urban area, limited land probably would require some other type of waste treatment system.

The data collected from the laboratory-scale activated sludge unit, after the system had reached a steady-state condition at each set value of sludge age, are summarized in Table 3. The effluent soluble COD was not dependent on sludge age, θ_S, and COD removal averaged 93% for all values of θ_S (Fig. 5). The total suspended solids in the effluent increased with sludge age. The regression equation (Fig. 5) shows that the concentration of suspended solids was more than three times as great at a sludge age of 8 days as at a θ_S of 1 day. However, at the sludge age for observed optimum sludge settling characteristics, 3-3.5 days, the concentration of suspended solids was only about 50-60% greater than that at a sludge age of 1 day. Based on the concentration of soluble COD and total suspended solids in the effluent, the performance of the system differed little among sludge ages.

The efficiency of removal was more variable for fat than for COD or for total suspended solids, but was not dependent on sludge age. Considering all sludge ages, the activated sludge system removed 91% of the fat in the raw waste and effectively degraded the fat in the wastewater.

The concentration of the biomass in the reactor ranged from 1208 to 4687 mg MLVSS/l and varied with sludge age. The average pH of the mixed liquor was 6.0-6.3. The average reactor dissolved oxygen concentrations and mixed liquor temperatures varied, but were not dependent on sludge age (Table 3).

The activated sludge process removed an average of 88% of the total nitrogen in the wastewater, but removal efficiencies ranged from 65 to 98%. In general, the total nitrogen concentration in the effluent decreased with increases in biomass concentration in the reactor and in sludge age. A plot of the steady-state data (Fig. 6) showed that concentration of total nitrogen in the effluent decreased exponentially with increased biomass concentration. The concentration of phosphorous in the effluent showed just the opposite trend. Phosphorous

Table 3. Summary Of Steady-State Data Collected From The Laboratory-Scale Activated Sludge System

Solids Wasting Rate 1/day	Sludge Age Day	Biomass Concentration MLVSS, mg/1	Reactor Conditions			COD		T.S.S.		Fat	
			pH	D.O. mg/1	Temperature °C	Inf. mg/1	Eff. mg/1	Inf. mg/1	Eff. mg/1	Inf. mg/1	Eff. mg/1
IV	0.98	1208	6.0	7.6	20.0	1126	68	355	8	174	5
0.5V	1.93	2248	6.2	5.8	20.3	1097	119	320	17	178	5
.29V	3.26	2306	6.2	5.2	20.8	905	39	297	15	246	5
.14V	5.91	3120	6.0	5.8	20.1	1216	76	292	26	80	23
.10V	8.11	4687	6.2	4.4	20.5	1582	116	438	30	154	6
.07V	8.25	2271	6.3	6.3	19.9	983	65	248	31	109	13

Solids Wasting Rate 1/day	Total (Kjeldahl) N		Ammonia-N		Nitrate-N		Nitrite-N		Phosphorous	
	Inf. mg/1	Eff. mg/1	Inf. mg/1	Eff. mg/1	Inf. mg/1	Eff. mg/1	Inf. mg/1	Eff. mg/1	Inf. mg/1	Eff. mg/1
.IV	75	7	2.3	5.5	0.8	8.8	0.04	0.2	4.2	0.9
0.5V	73	10	1.6	3.1	.1	0.6	.01	.1	5.1	2.0
.29V	82	7	1.7	3.0	.5	10.6	.04	.4	5.8	2.9
.14V	89	3	2.0	2.0	.8	9.2	.05	.7	7.1	3.2
.10V	94	2	1.3	7.2	.4	5.9	.05	.6	8.1	4.6
.07V	86	30	3.6	1.8	.2	1.8	.03	1.1	4.6	3.0

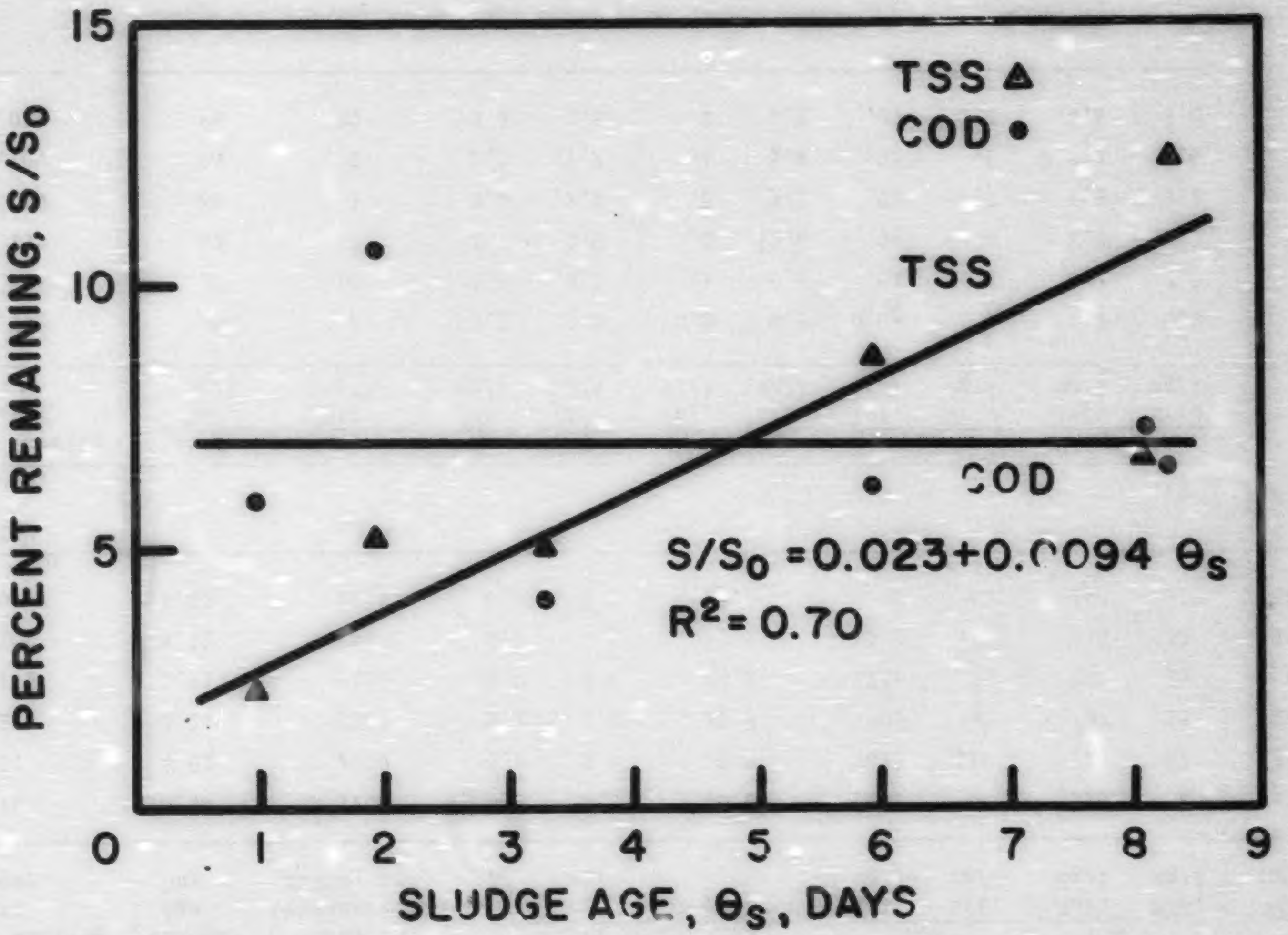

Fig. 5 Percent effluent COD and total suspended solids concentration, S/S_0, as a function of sludge age, θ_S, in the laboratory-scale activated sludge unit.

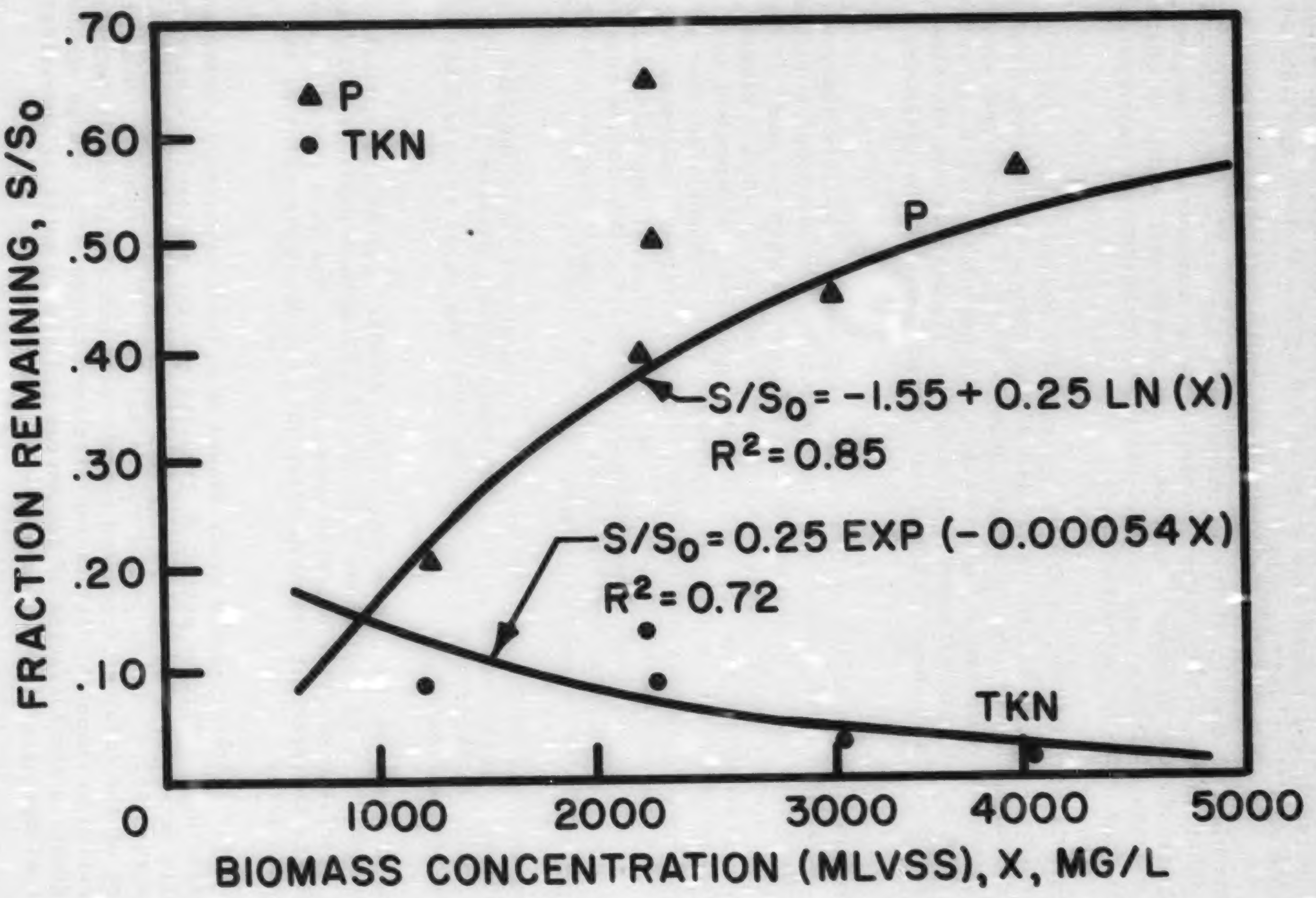

Fig. 6 Fraction of phosphorous and total nitrogen remaining in the effluent as a function of biomass concentration for the laboratory-scale activated sludge unit.

concentration increased logarithmically with biomass concentration and sludge age (Figs. 6 and 7) and ranged from a low of 0.9 mg P/1 at 1208 mg MLVSS/1 to a high of 4.6 mg P/1 at 4687 mg MLVSS/1.

The concentrations of ammonia-nitrogen, nitrate-nitrogen and nitrite-nitrogen were all higher in the effluent than in the untreated wastewater. The ammonia-nitrogen concentration in the effluent was about double that of the untreated water. The average nitrate- and nitrite-nitrogen concentrations increased to about 12-15 fold those of untreated waste.

Based on overall performance, at the sludge ages for optimum sludge settling characteristics (2-3.5 days), the activated sludge system could be expected to reduce concentration of total nitrogen about 90% and of phosphorous about 50-60%. However, at this operating condition, the ammonia-nitrogen concentration would double, nitrate-nitrogen would increase 12-15 times and nitrite-nitrogen in the effluent about 10 times the concentration of the untreated waste.

The kinetic coefficients of the activated sludge system for poultry processing waste were also determined. Trial-and-error solutions for the Monod equation (Fig. 3) showed that the specific growth rate, $\hat{\mu}$, was between 1.5 and 2.0 day^{-1}, and K_S, the saturation coefficient, was between 20 and 24 mg COD/1. However, the specific substrate utilization rate, U, was essentially independent of substrate COD concentration and is best expressed as a constant value for all sludge ages of 1.5 mg COD per day per mg MLVSS. This constant indicates that the activated sludge system was capable of daily utilizing or degrading 1.5 gm of soluble COD per gm of mixed liquor volatile suspended solids in the reactor. At a sludge age of 3.26 days, the system was capable of utilizing daily about 3.5 gm of COD per liter of reactor volume.

A regression analysis on the data showed that the observed yield declined exponentially with sludge age (Fig. 9). The yield curve indicates that daily yield was between 0.3 and 0.1 mg MLVSS per mg of soluble COD removed from the wastewater.

A regression analysis on the growth rate, $1/\theta_S$, plotted against the specific utilization rate, U, (Fig. 10) shows that the yield was 0.39 day^{-1} (mg COD/day per mg MLVSS) and the specific organism decay rate, k_d, was 0.34 day^{-1}. Based on this analysis the specific organism decay rate was about one-fifth of the specific growth rate.

In summary, this laboratory-scale study showed that the conventional activated sludge process is an effective method of treating poultry processing wastewater. At a hydraulic detention time of 6 hours, the system removed 93% of the soluble COD and more than 90% of the suspended solids and fat. The process reduced the concentration of the total nitrogen and phosphorous, but significantly increased the concentration of ammonia-, nitrate-and nitrite-nitrogen. The sludge age had a notable effect on the operation of the system and sludge settling characteristics were best at sludge ages of 2-3.5 days.

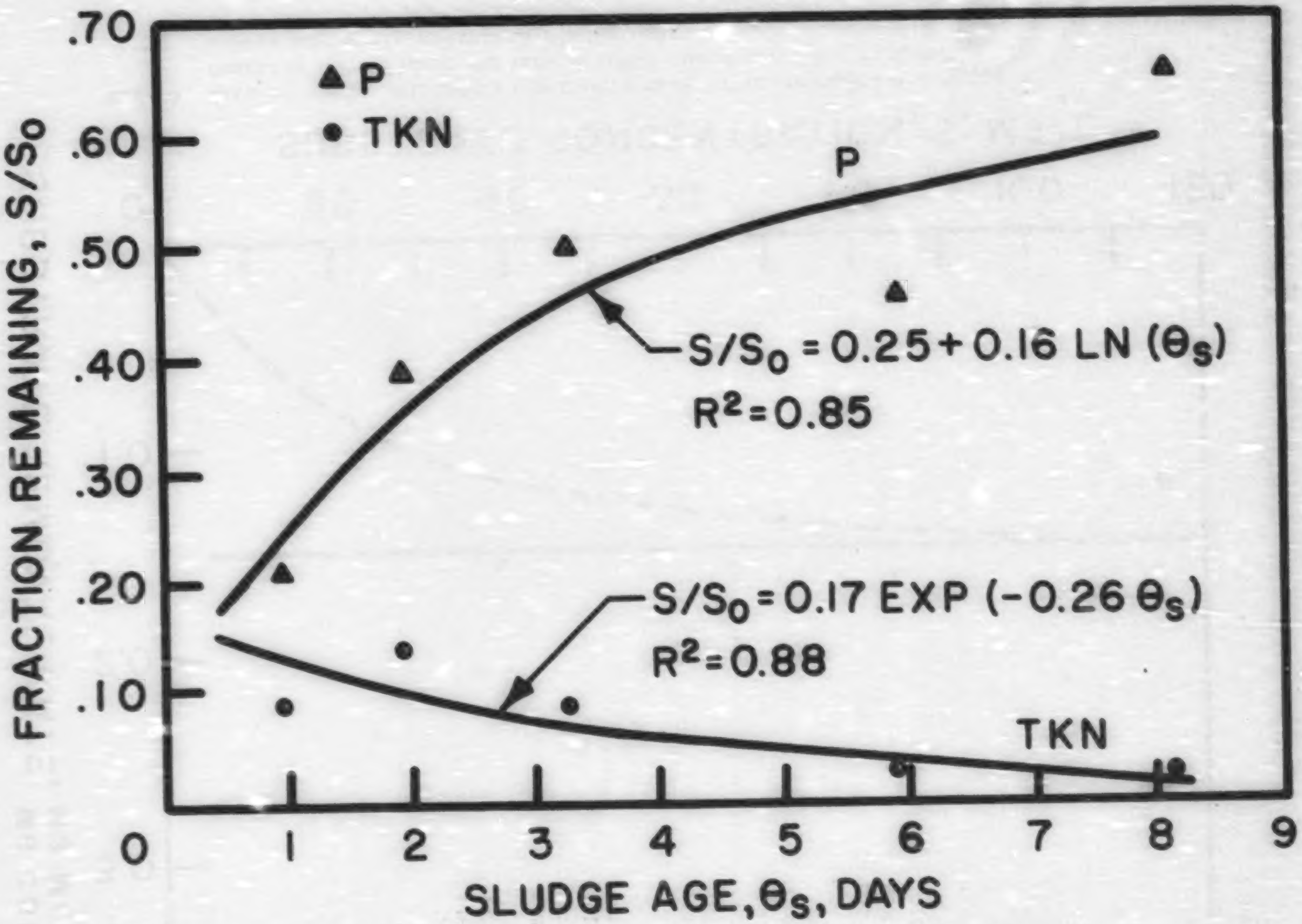

Fig. 7 Fraction of phosphorous and total nitrogen remaining in the effluent as a function of sludge age for the laboratory-scale activated sludge unit.

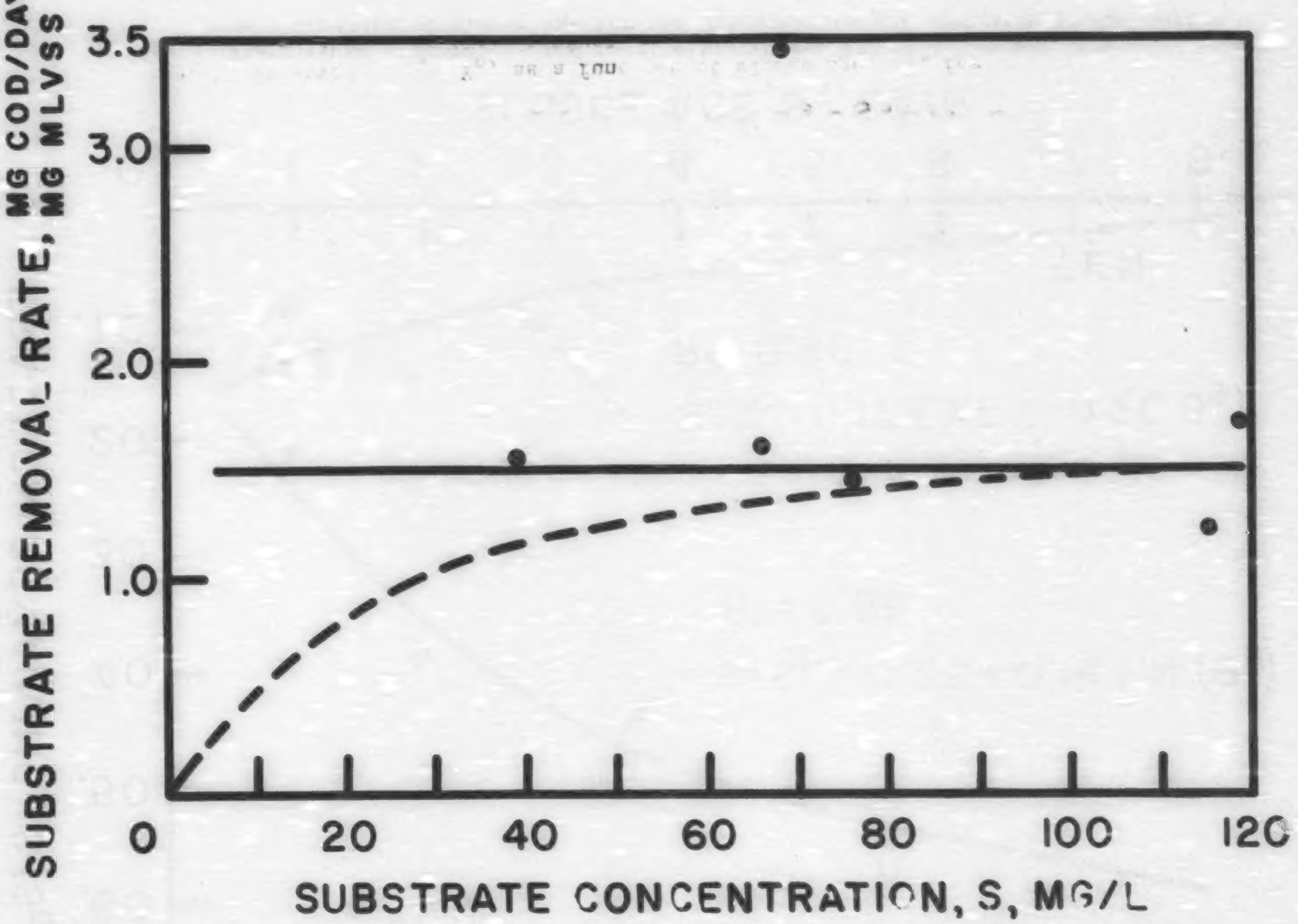

Fig. 8 Rate of waste utilization per unit mass of microorganisms, U, as a function of effluent substrate (COD) concentration, S, for the laboratory-scale activated sludge unit.

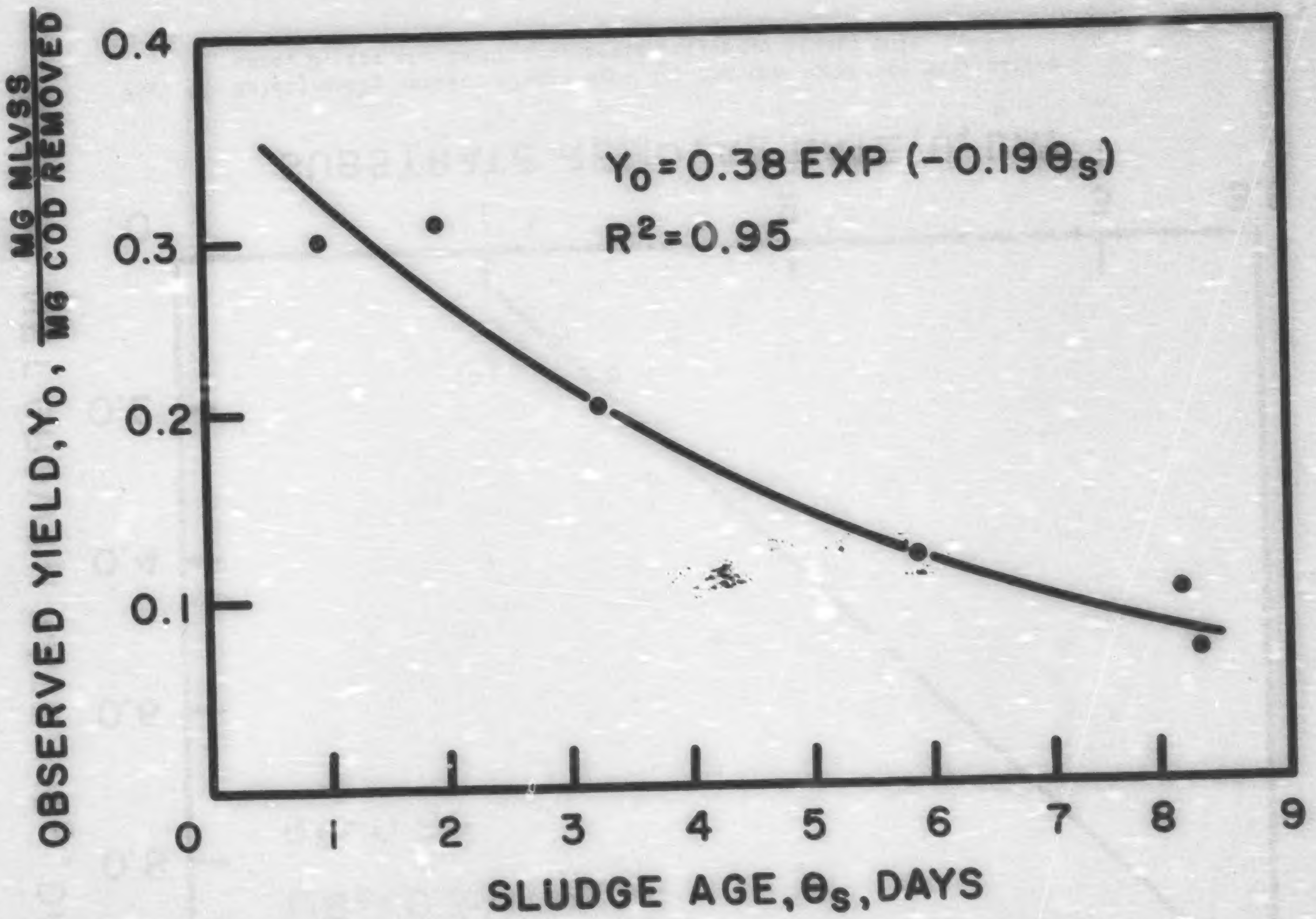

Fig. 9 Observed yield, Y_O, as a function of sludge age, θ_S, for the laboratory-scale activated sludge unit.

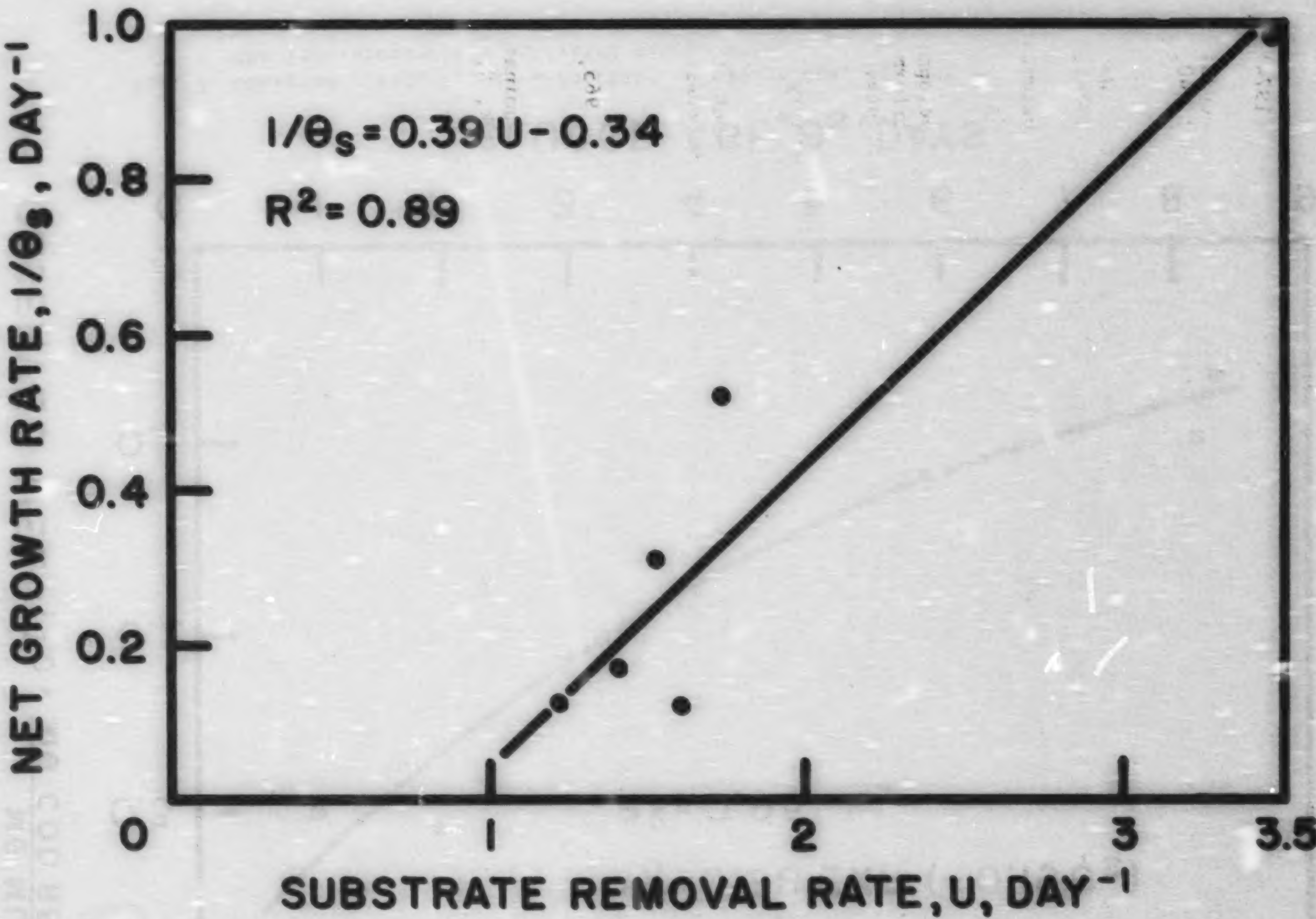

Fig. 10 Relationship between sludge age, θ_S, and the substrate utilization rate, U, for the laboratory-scale activated sludge unit.

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A MEAT PACKER'S SOLUTION TO MEETING 1983 EFFLUENT REQUIREMENTS

by

Joseph A. Homel, Jr., P.E.* and Jack McVaugh, P.E.**

INTRODUCTION

The 1983 National Pollution Discharge Elimination Standards (NPDES) discharge standards will force dischargeers of industrial wastes to perform virtually complete wastewater cleanup, paving the way toward total water reuse. For a meat packer to meet these standards for stream discharge, biochemical oxygen demand (BOD_5), suspended solids (SS), grease, and nutrients may have to be reduced in some cases by 99+%.

Many meat packers in urban areas have the opportunity to shift part of the responsibility for meeting 1983 standards to the local municipality. The municipality agrees to accept the wastewater and to comply with the state regulatory authority's treatment standards. The packing company essentially agrees to pay a hookup and user fee and promises to remove substances from the wastewater which would otherwise cause damage to the sewer and treatment plant, or that would upset the treatment process.

For other meat packers, however, it is neither economical nor practical to discharge into a municipal sewer system. These packers must build, maintain and operate their own primary, secondary, and tertiary treatment systems. Ideally, the common objective of treatment plant design is to incorporate a series of complimentary processes, which are economical with regard to capital, operating and maintenance costs. Each process must not only be designed to operate at the desired level of efficiency during normal operation, but must contain sufficient conservativeness in design to "take up the slack" should the preceding process or processes fail.

The most critical process may then be the last major treatment unit in the sequence - the "polishing" unit. At present, however, perhaps the least amount of attention is given to this unit. An often used polishing unit is the detention pond. Wisconsin regulations, as well as those of several other states, require that biological secondary treatment systems be followed by detention ponds of up to 30 days capacity. Because of the high nutrient content of their wastewaters, however, many meat packers have discovered that these ponds often generate their own waste load in the form of algae.

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*Vice President, Foth & Van Dyke & Associates, Inc., Green Bay, Wisconsin.

**Industrial Process Engineer, Envirex Inc., Waukesha, Wisconsin.

This report describes the design and operating experience of a meat packing plant waste treatment system. The system is currently meeting present permit requirements and investigations are ongoing which will allow the effluent to meet 1983 standards. Each process in the treatment sequence was designed to accept surge loadings, and the final polishing step has shown promise in overcoming some of the disadvantages of the detention pond.

BACKGROUND

Hillshire Farm Inc., a division of Consolidated Foods Inc., operates a meat packing plant in New London, Wisconsin. The plant presently slaughters approximately 1500 hogs/day, and conducts complex processing of the hog carcasses as well as purchased beef carcasses.

Early in 1972, the State of Wisconsin Department of Natural Resources issued a statement requiring Hillshire to reduce its wastewater BOD_5 and SS concentration to maximums of 35 mg/l (a 90+% reduction), and reduce total phosphorus by 85%. At that time, wastewater treatment consisted of collection of kill floor, processing plant, and domestic waste, and passage through a septic tank system.

Discharge to the municipal waste treatment system was first investigated as a possible means of waste disposal. In order to discharge to the city's system, first the New London city limits would have had to be extended outward to incorporate the plant site; and secondly, a pump station as well as extension and enlargement of the main interceptor sewer would have been required to handle the significant increase in flow. Total cost (1972 dollars) for the lift station and interceptor construction was estimated to range from $680,000 to $750,000 and was expected to be financed by Hillshire Farm. Moreover, the company would have realized increased 1972 property taxes in excess of $40,000 by incorporation with the city, and yearly sewage surcharge fees would have approximated $25,000 (1972 dollars).

In the spring of 1972, a consulting engineer was retained to recommend possible methods of onsite wastewater treatment for stream discharge. At that time the flow was measured, and working closely with the plant management, future flows were projected. The measured flow rates, as well as projected flow rates which were used for plant design, are compared with present-day flow rates in Table 1.

TABLE 1. MEASURED (1972), PROJECTED, AND PRESENT (1976) RAW WASTEWATER FLOW RATES (GPM)

	Measured	Projected	Present
Average	173	254	230
Peak	273	400	400

A wastewater sampling program was carried out on raw wastewater, septic tank effluent, and on grab samples taken from various locations along the creek into which the wastewater flows. (The septic tank was the only existing means of treating the domestic and industrial waste waters in 1972.) The stream winds through marshy farmland and residential areas before discharging into the Wolf River. Results of analyses conducted on these samples are shown in Table 2.

TABLE 2. RESULTS OF ANALYSIS OF SAMPLES TAKEN 5-3-72 (mg/l)

Location	BOD_5	SS	Total P	Grease
Septic Tank Influent	735*	513	12.25	548*
Septic Tank Effluent	390*	373	12.5	130†
150 yds. Downstream	300	260	10.75	33
2.5 mi. Downstream	16	52	11.25	—
5.0 Downstream	5	25	11.5	--

*12 hr. composite samples
†24 hr. composite sample

Composites were also made of 12 hr. composite "workday" samples with 24 hr. composites which included production plus cleanup periods. Table 3 shows the results of analyses on composite samples of septic tank influent and effluent.

TABLE 3. RESULTS OF ANALYSIS OF SEPTIC TANK COMPOSITE SAMPLES (mg/l)

	12-hr. "workday" comp.		24-hr. comp.	
	Influent	Effluent	Influent	Effluent
BOD_5	735	390	545	368
SS	590	500	485	475
Total P	157	27.0	94.9	25.8
Grease	548	--	--	130

SELECTION OF UNIT PROCESSES

The present wastewater treatment plant at Hillshire Farm consists of a rotary screen on kill flow wastes, a lift station, dissolved-air flotation complete mix activated sludge, chlorine contact, and final detention in a pond filled with marsh vegetation. Because of the difficulties in separating various process sewer lines in the older sections of the plant, the various streams are combined before being pumped into the flotation unit. The streams emanate from the kill floor, processing area, washrooms, garage and maintenance area. Blood is recovered, hides and renderable material are processed offsite, and stormwater runoff does not enter the treatment system.

The following is a discussion of the selection criteria and design of each of the unit processes. Figure 1 shows the process flow scheme.

Screening

In meat packing plant wastewater the greatest source of gross suspended solids consists of fleshings and paunch from the kill floor. Because of the large quantity of marketable by-product to be removed from the wastewater at this location, a rotary drum screen had previously been installed on the kill floor wastewater stream. The drum is 6 ft. diameter with a 10 ft. face width, and is covered with a 20 mesh screen. Lesser amounts of gross solids are collected in wire baskets in each of the floor drains throughout the processing area.

Pumping

Pumping is often required to introduce wastewater into a treatment plant with several unit processes. Once pumped, the main process stream flows by gravity through each of the unit processes and into the receiving stream. A wastewater lift station usually consists of a wet well or sump, into which the sewer or sewers discharge, and a dry well containing several pumps. A level control device in the wet well commands each of the pumps to start and stop, maintaining the wastewater level between maximum and minimum values. The configuration of flow leaving the lift station, then, is characterized by surges, the significance of which is very great for two or three pump lift stations. These sudden surges may have a disturbing effect on the unit process immediately following.

At the Hillshire Farm treatment plant, the unit process into which the wastewater is pumped is the dissolved-air flotation unit. Although designed to provide maximum hyudraulic stability, the unit performs best when not subject to intense hydraulic surges. A large equalization basin, out of which the collected wastewater is pumped at a constant rate, has been used to equalize many types of industrial wastes. However, packing plant wastes would require intense mixing to prevent separation of grease and settleable solids in areas where they cannot be mechanically removed.

A compromise plan was reached through the use of variable speed pump, operating from a proportional level control signal in a large sump. By automatically matching the pumping rate to the rate at which wastewater enters the sump, the system takes advantage of the flow rate dampening effect of the sewer lines and the diverse schedule of water usage inherent in a large complex packing plant.

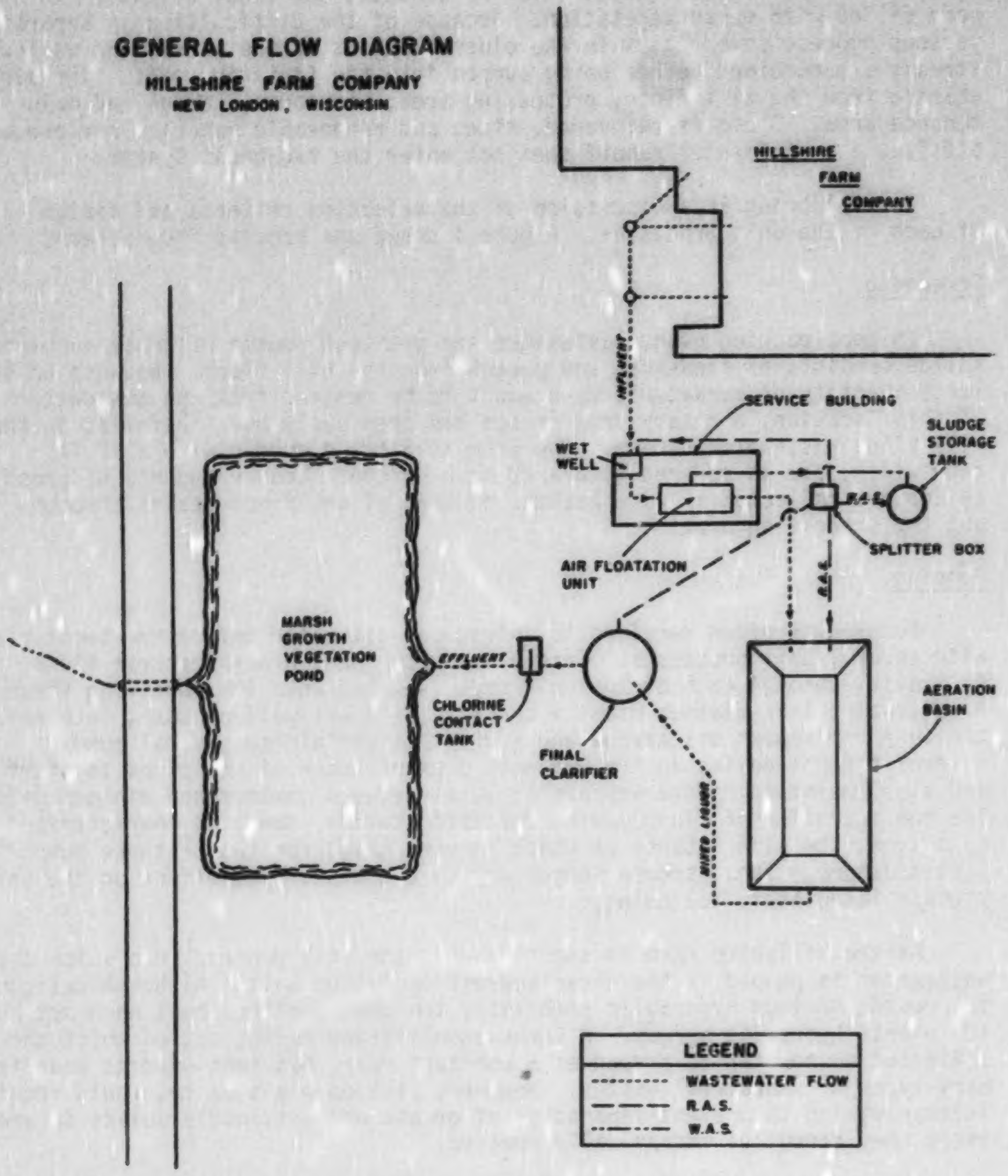
GENERAL FLOW DIAGRAM
HILLSHIRE FARM COMPANY
NEW LONDON, WISCONSIN
HILLSHIRE
FARM
COMPANY
INFLUENT
SERVICE BUILDING
WET WELL
SLUDGE STORAGE TANK
R.A.S.
SPLITTER BOX
AIR FLOATATION UNIT
R.A.S.
MARSH GROWTH VEGETATION POND
EFFLUENT
CHLORINE CONTACT TANK
FINAL CLARIFIER
AERATION BASIN
MIXED LIQUOR
LEGEND
WASTEWATER FLOW
R.A.S.
W.A.S.

FIGURE 1 - GENERAL FLOW DIAGRAM

The lift station consists of two variable speed horizontal trash pumps of recessed impeller design. The control system consists of an SCR type infinitely variable speed controller commanded by a bubble tube level sensing device in the wet well.

Dissolved-Air Flotation

Primary treatment at Hillshire Farm is accomplished by dissolved-air flotation. Its purpose is to remove free grease and suspended solids which would only slowly degrade during subsequent biological treatment.

The initial design was approached in two ways, 1) being a unit without chemical addition or flocculation, intended to remove all free grease and 50% of the SS, and 2) being a unit with chemical addition and flocculation for removal of essentially all free and emulsified grease and up to 90% of the SS. the former design approach was chosen, with facilities reserved, however, for the future addition of chemical feed equipment.

The unit installed is of rectangular deesign with reaction-jet dished - baffle influent distribution and energy dissipation device. This influent arrangement distributes the flow over the full width and depth of the flotation compartment, thereby maximizing hydraulic stability through plug-flow configuration. The unit consists of a steel tank 8' wide by 36' long with 4' of effective water depth. The tank has a hopper bottom with independently operated surface skimmer and longitudinal screw bottom sludge collector. Skimmings and sludge flow by gravity into a common sump, where they are pumped by means of heavy-duty positive displacement pumps into a sludge storage tank. The combined sludge then awaits land spreading.

The flotation unit uses the recycle pressurization method of inducing dissolved air into the waste stream, thus maximizing controllability and power usage efficiency. The unit is sized for a peak raw flow of 400 GPM and a recycle flow of up to 150 GPM, pressurized to 40 psig. At this peak flow rate, the tank provides an effective detention time of approximately 14 minutes.

Secondary Treatment

Secondary treatment was obviously required to meet the effluent quality needs for stream discharge. Physical-chemical means, including activated carbon were briefly surveyed, but the costs indicated by the results of a bench scale testing program were prohibitive. Likewise, land spreading of the primary effluent was ruled out because of the incomplete technology of the day, and because of the cold Wisconsin climate.

Because of the successful documented operating experiences, biological treatment was deemed the most practical means of accomplishing secondary treatment. An economic evaluation of four candidate methods was conducted, the results of which are summarized in Table 4. Also, design criteria and a cost summary for each of the competing candidate processes are presented in the appendix. Processes considered included rotating disc contactor, contact stabilization, anaerobic-aerated lagooning, and complete mix activated sludge. Capital costs included those of the secondary treatment process and a holding pond, with detention time as dependent on the process which preceded it and equalled 10 days for all candidates except the anaerobic-aerated lagoon system. That process required a 30 day detention time.

TABLE 4. CAPITAL AND OPERATING COST AND MANPOWER ESTIMATES FOR BIOLOGICAL TREATMENT METHODS. (1972 DOLLARS) ADD AIR FLOTATION AND CHLORINATION COST WHICH IS COMMON TO ALL ALTERNATES

	Capital Cost Add Air Flotation ($)	Operating Cost ($/yr)	Manpower Required (manhours/day)
Rotating Disc Contactor	197,190	7,800	3
Contact Stabilization	170,880	12,400	5
Anaer-Aerated	200,663	12,700	3
Activated Sludge	122,428	12,400	5

The activated sludge method was selected because of low capital investment. When considering both capital and operating costs, the rotating disc contactor method appeared attractive, but could not be recommended without extensive pilot testing to verify design assumptions. The use of anaerobic lagoons was ruled out, not only because of price but because of the potential for odor in the surrounding community.

The activated sludge system consists of a 275,000 gallon epoxy coated concrete aeration basin with diffused air furnished through a fixed header system. Because of the basin configuration and inlet arrangement, the system is considered to be completely mixed. Air is supplied to the 78 diffusers at a rate of 14 CFM/diffuser by two 100 HP centrifugal blowers. At a BOD_5 removal rate of 1000#/day and the design mixed liquor volatile suspended solids (MLVSS) concentration of 3000 mg/l, the food:mass (F:M) ratio is calculated to be .15. A 30 foot diameter final clarifier with scraper type sludge collection mechanism and skimmer is used to clarify the mixed liquor. Sludge collected in the clarifier sludge sump is pumped at a maximum rate of 275,000 GPD, to a splitter box after which it is returned to the aeration basin.

Excessive activated sludge may be wasted from the splitter box into the sludge storage tank by opening a gate valve and permitting gravity flow. The waste activated sludge then joins the air flotation scum and sludge in the sludge storage tank to await land spreading. The storage tank is 10 ft. diameter x 19 ft. side water depth, and is equipped with the necessary gas safety devices such as pressure relief valve, vacuum breaker and flame resistor.

Chlorination System

The state regulatory agency requires chlorination wherever pathogenic organisms may be contained in the wastewater stream. In the Hillshire Farm system, a baffled chlorine contact chamber follows secondary clarification. The chamber is sized to provide approximately 20 minutes detention time at the peak flow of 400 GPM.

A manually controlled, vacuum-type, tank mounted chlorinator is used to deliver up to 60 lb/day chlorine into the contact tank.

Control Building

A concrete block building is used to house the lift pumps and SCR control system, rotary blowers, dissolved-air flotation unit, nominal laboratory facilities, and provides a future site for chemical feed equipment. Although in the initial design it was not intended to house the flotation unit, it was felt that the maintenance benefit of enclosure would outweigh the additional building costs.

Effluent Polishing

The effluent polishing unit in the Hillshire Farm treatment system consists of a detention pond filled with marsh vegetation. Observing how effective the wastewater was treated by the existing stream and marsh vegetation originally located on the plant property (See "150 yards downstream" in Table 2), some interest was generated in exploring this method as a means of secondary treatment. A demonstration grant was sought in order to explore the concept on a four season basis, as treatment efficiency was suspected to be sufficient at low winter temperatures. Demonstration grant funds were not available however, and thought was abandoned as to using this method for secondary treatment. Effluent polishing was a different factor, however.

At the time of process selection at Hillshire, several studies on bull-rushes for wastewater treatment were being proposed in this country, apparently inspired by some successful pilot work on phenolic wastes in Germany. In that country, the Max-Planck Gesellschaft and Gottingen University had spent several years researching the mechanism by which higher plants, such as the bull-rush Scirpus locustris heterotrophically metabolized organic material. Even toxic organics, such as phenols, were tolerated and metabolized in high concentrations according to tracer studies. A bactericidal effect was also attributed to the bull-rushes, allegedly through the production of organic "phytoncides". The research resulted in a pilot study, using a cascade growth of bull-rushes to further treat municipal secondary effluent. The study indicated virtually complete BOD$_5$ and SS removal at loading of 7.5 GPD of wastewater per ft^2 of bull-rush pond. Removals during winter conditions were reduced by approximately 40%.[1,2,3]

Interest in the process led to construction of a marsh growth vegetation pond downstream of the chlorine contact tank. The pond is essentially an unlined earthen lagoon approximately 220 ft. square and 10 ft. in depth containing a natural assortment of higher plants native to the locale.

Water level in the pond is controlled by a concrete block effluent structure, which directs the final discharge into a cast iron pipe.

Some of the marsh grass species growing in the pond have been identified as Common Millein (Verbascum thapsus), Cattail (Typha latifolia), and grasses of the family Graminear.

UNIT PROCESS PERFORMANCE EVALUATION

A sampling program and study was undertaken recently to determine the effectiveness of each unit process in removing BOD_5, SS, oil and grease, and phosphorus from Hillshire Farm wastewater. The sampling consisted of grab and composite samples taken over the period between October, 1974 and January, 1976. After collection, each sample was packed in ice and transported within three hours to the consultant's lab for analysis. Verification of results was often made by two independent laboratories.

Table 5 summarizes the average values of the wastewater characteristics measured during the sampling program, and indicates removal efficiencies of primary, secondary, and marsh vegetation treatment. Influent samples were taken from the influent wet well just prior to pumping. Primary and secondary effluent samples withdrawn from the air flotation and final clarifier effluent wet wells, respectively, and marsh effluent from near the effluent structure in the marsh growth vegetation pond.

TABLE 5. AVERAGE VALUES OF WASTEWATER PARAMETERS (mg/l) AND PROCESS PERFORMANCE EFFICIENCIES

	Influent		Primary Effluent		Secondary Effluent		Marsh Effluent	
BOD_5	800	(24%)	610	(98%)	10	(30%)	7	(99% overall)
SS	480	(40%)	290	(95%)	14	(42%)	8	(98% overall)
Phosphorus (as P)	24	(38%)	15	(53%)	7	(0%)	7	(70% overall)
Oil and Grease	261	(70%)	80	--	--	--	6	(98% overall)

Table 6 shows average concentrations of solids and oil and grease in the various sludges throughout the plant.

TABLE 6. AVERAGE SOLIDS CONCENTRATIONS (% BY WEIGHT)

	Air Flotation Scum	Air Flotation Sludge	R.A.S.	Mixed Liquor
Total Solids	5.2	4.1	18	14
Suspended Solids	4.6	2.4	.7	.3
Oil and Grease	1.1	.2		

Influent Pumping

The effect of the variable speed influent pumping on the unit process following could not easily be evaluated, since the SCR control system cannot be altered to pump in the conventional "on-off" manner. However, data was generated to determine how effectively the pumping rate matched the flow rate into the influent wet well.

Readings from the plant's nozzle-type flow meter, installed ahead of the wet well, were compared to head-over-weir measurements made on the air flotation unit's straight edge effluent weir. Of course, the flotation pressurized recycle flow rate, measured by a differential pressure orifice plate and manometer on the recycle line, was subtracted from the flow rate value calculated by the head-over-weir measurement. Results showed only a slight dampening effect between the flow meter nozzle and the air flotation unit effluent weir. This could easily be attributed to inaccuracies in head-over-weir measurement, and to the dampening effect of the air flotation unit itself.

It was therefore concluded that the SCR control system paces the pumping flow rate very closely with the influent flow rate.

Dissolved-Air Flotation Unit

Table 5 indicates average BOD_5, SS and oil and grease removals of 24%, 40% and 70% respectively. Moreover, floated solids are thickened to a concentration averaging 5.2% by weight. Scum solids concentrations are maximized by operating the skimmer on a timed cycle. At present the skimmer operates for 5 minutes and is off for 10 minutes. The bottom sludge screw conveyor is operated manually once or twice per day just before and during flotation sludge wasting. The unit appears to be operating efficiently although it is operating at peak capacity.

Secondary Treatment

Table 5 indicates that the activated sludge system is producing a high quality effluent, with average BOD_5 and SS concentrations in compliance with most state standards for stream discharge. BOD_5 and SS concentrations were 10 and 14 mg/l, respectively, while the effluent phosphorus concentration (as P) was 7 mg/l. The 70% phosphorus removal fell short of the NPDES requirement for 85% removal. Sufficient data on oil and grease removal was not available to establish a meaningful average.

Analysis of mixed liquor samples, as shown on Table 6, indicates that the mixed liquor suspended solids (MLSS) is being maintained at the design level of 3000 mg/l and that the return activated sludge (R.A.S.) SS concentration averages 7000 mg/l. At the present day average flow of 330,000 GPD, an F:M ratio of .24 is calculated (based on MLSS concentration, BOD_5 = 610 mg/l). At this F:M, a good settling biological floc is produced and the clarifier effluent is clear. Infrequent upsets to the system do occur but are usually corrected within a few days.

Effluent Polishing

Analyses of grab samples taken near the effluent structure of the marsh growth vegetation pond, revealed average BOD_5, SS, and grease concentrations of 7, 8, and 6 mg/l, respectively. Corresponding removals for these substances across the pond were 30% and 42% for the BOD and SS, respectively. The marsh vegetation apparently had no significant effect on phosphorus removal.

Table 7 presents the analytical results of the pond effluent semimonthly sampling program over the period between November, 1974 and December, 1975. BOD_5 and oil and grease analyses were conducted in the consultant's laboratory with frequent verification by two independent laboratories. SS analyses were conducted at the Hillshire Farm plant site. It is difficult to see any significant trends in effluent quality which can be related to cold weather, but higher values of BOD_5, SS and oil and grease were evident in November, 1974 through March, 1975 samples. (See Table 7). If truly temperature related, such a trend should then repeat itself in 1976. Nonetheless, all effluent parameters were in compliance with the existing NPDES permit. Moreover, at no time of the year did effluent SS concentrations indicate a significant production of algae, which would be expected in a conventional detention pond richly supplied with nutrients.

PHOSPHORUS REMOVAL STUDY

In order to meet Wisconsin's stream discharge requirements in 1977, Hillshire Farm must increase its phosphorus removal levels from the present 70% to 85%. An intensive literature search by Hillshire Farm's consultant revealed that of the three inorganic chemicals commonly used for phosphorus removal, lime, alum, and ferric chloride, researchers in general found the ferric salt to be the most effective.

The various studies also indicated three possible addition point locations for the inorganic and polyelectrolyte coagulant aid. One possible location will be the pipeline or influent wet well preceding the air flotation unit. Another possibility will be at the head end of the aeration basin, and the third will be approximately two-thirds of the way down its length.

TABLE 7. MARSH GROWTH VEGETATION POND EFFLUENT QUALITY (mg/l)

Date	BOD_5	SS	Oil & Grease
11-7-74	39	53	
1-10-75	19	20	
1-31-75	9	8	9.5
2-14-75	10.5	34	9.9
2-28-75	15	1	14.7
3-14-75	14.5	3.2	5.6
3-31-75	10	15.2	8.9
4-14-75	4.5	8.4	10
4-25-75	12	16.4	4.3
5-29-75	23	31	7.9
6-4-75	30	--	5.7
6-20-75	10	--	4.7
7-1-75	6.8	5.6	1.6
7-18-75	6.1	3	2.5
7-30-75	2.4	34	5
8-15-75	1.6	9	3.5
8-29-75	4.5	--	1.8
9-17-75	2.1	--	2
9-26-75	3	7.2	1.9
10-16-75	12.9	--	5.8
10-28-75	3.1	3	5.2
11-19-75	8	4.4	5.4
11-26-75	4.2	7.5	2.4
12-29-75	3	--	5.4
12-31-75	3	--	2.1

Bench scale coagulation studies on Hillshire Farm's clarifier effluent indicated that the state's requirements could be met by the addition of 150 mg/l of ferric chloride and 0.5 mg/l of an anionic polyelectrolyte. Chemical coagulation tests and bench scale dissolved-air flotation tests were also conducted on raw wastewater to estimate the potential for BOD_5 and phosphorus removals in the air flotation unit.

Preliminary results from flotation test work were inconclusive. Because of the apparently low alkalinity of the raw wastewater, both ferric chloride and alum in dosages between 100 mg/l and 300 mg/l depressed the pH below 5.0. This is the commonly accepted lower limit for the optimum coagulation of the hydroxides of aluminum and iron. This indicates, therefore, that on a full scale basis a three-chemical feed system - coagulant, polyelectrolyte, and possibly lime for pH adjustment, would be required for chemical addition ahead of the air flotation unit. Bench scale flotation test results are shown in Table 8 using 200 mg/l alum and 2 mg/l of an anionic polyelectrolyte* at a pH of 4.8. The test was run with 50% recycle and a detention time of 7 minutes. The bench scale apparatus is sketched in Figure 2. Although an aluminum hydroxide floc had been formed, colloidal grease particles and blood cells had apparently not been adsorbed onto the floc and removed efficiently. More experimentation will be required to determine the optimum chemical, dosage, and pH.

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*Betz 1120A; Betz Laboratories, Inc., Trevose, Pennsylvania

TABLE 8. RESULTS OF BENCH SCALE DISSOLVED-AIR FLOTATION TESTS WITH AND WITHOUT CHEMICAL COAGULATION

	Raw Influent	Flotation w/o Chemical	Flotation w/Chemical
BOD_5	720	585	490
SS	233	110	95
Phosphorus	2		--
Oil and Grease	110	23	14

CAPITAL AND OPERATING COSTS

The Hillshire Farm wastewater treatment plant was installed in 1973 at a total cost of $350,000. Annual operating cost in 1975, including electricity, chlorine, 40 man-hours per week for operation and less than 5 extra man-hours per week for maintenance totalled $25,000.

CONCLUSIONS

This report describes the design and operation of a meat packing plant wastewater treatment system, discharging its effluent into a small stream. In this instance, the packing plant realized capital cost savings of up to $400,000 and yearly expense savings of up to $40,000 by installing their own treatment system, rather than discharging to the local municipal sewer system.

The treatment system is producing effluent of a quality greater than the discharge permit requires. Analyses of each of the unit processes indicates that each are performing well under maximum design loadings. In addition to the present BOD_5, SS, and oil and grease removals, increased phosphorus removal appears feasible through the addition of ferric chloride to the aeration basin.

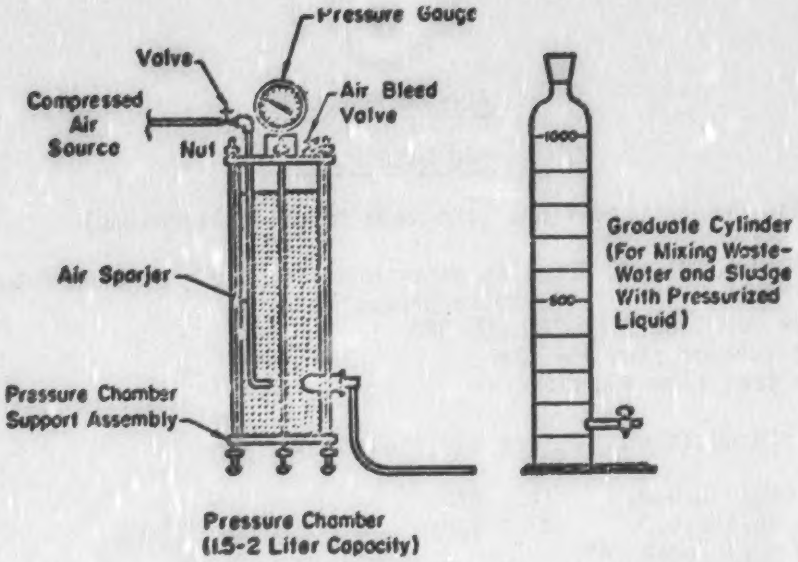
Pressure Gauge
Valve
Compressed Air Source
Air Bleed Valve
Nut
1000
Graduate Cylinder (For Mixing Waste-Water and Sludge With Pressurized Liquid)
500
Air Sparjer
Pressure Chamber Support Assembly
Pressure Chamber (1.5-2 Liter Capacity)

FIGURE 2
BENCH SCALE DISSOLVED-AIR FLOTATION TEST APPARATUS

REFERENCES

1. Czerwenka, W., Seidel, K., "New methods for goundwater enrichemnt in Krefeld." GWF 106 (30), 828-833, (1965).

2. Foth & Van Dyke and Associates, *Preliminary Engineering Report for Wastewater Treatment Facilities at the Quality Packing House, Inc., in New London, Wisconsin*, Green Bay, June 1972.

3. Althaus, H., "Biological waste treatment with bullrushes", GWF, 107, (18), 486-488, (1966).

APPENDIX

ALTERNATE NO. 1

BIO DISC PLANT

I. Bio Disc Design Conditions (the same for all alternates)

Design flow-275,000 GPD (The owner provided the projected future packing house production.)
12 hour work day flow-250,000 GPD
Design average flow-254 GPM
Design peak flow-400 GPM

Raw waste contain: (before air flotation)

735	mg/l	B.O.D.	1685 #/da
2050	mg/l	C.O.D.	4702 #/da
13.0	mg/l	Total "P"	
68.4	mg/l	Organic Nitrogen	
4800	mg/l	Total Solids	11,009 #/da
590	mg/l	Total Suspended Solids	1353 #/da

Assuming we receive a reduction of 40% in B.O.D. and 50% in suspended solids from the air flotation unit, we shall design the secondary unit for the following:

Design flow-275,000 GPD
12 hour work day flow-250,000 GPD
Design average flow-254 GPM
Design peak flow-400 GPM

The primary waste effluent will contain:

441 mg/l B.O.D. - 1011 #/da B.O.D.
1230 mg/l C.O.D. - 2821 #/da C.O.D.
2400 mg/l Total Solids - 5504 #/da Total Solids
295 mg/l Total Suspended Solids - 676 #/da Total Suspended Solids

Less than 100 mg/l Grease - 229 #/da Grease

Required Effluent 35 mg/l B.O.D.
25 mg/l S.S. (assumed)
2 mg/l Total Phosphorus
Less than 100 mg/l Total Grease

Assuming we receive 40% B.O.D. removal through air flotation, 93% removal through bio disc system will be required to meet effluent standards set forth by the Department of Natural Resources.

II. Bio Disc System with Clarifier Capital Cost (1972 Dollars)

Sub-Total (Add Air Flotation Cost) $197,190.00

No enclosure included for the above equipment.

III. Bio Disc System with Clarifier Estimated Operating Costs (1972 Dollars)

Annual power costs (est. connected HP 52) $ 6,812.00
(Based on buying power for $0.02 per KWH)

In addition the system would require approximately three hours of maintenance per day.

Chemical cost (chlorine) $2.75 per day (Estimated)

ALTERNATE NO. 2

CONTACT STABILIZATION PLANT

I. Design Conditions (Also see design conditions for Alternate No. 1)

Raw B.O.D. is 1685 pounds per day less 40% B.O.D. removal in the air flotation unit, leaving 1011 pounds per day B.O.D. in the primary effluent. Therefore, a B.O.D. removal of 93% is required through the secondary portion of the plant to meet the required effluent standards.

II. Contact Stabilization Plant Capital Cost (1972 Dollars)

Sub-Total (Add Air Flotation Cost) $170,880.00

No enclosure included for the above equipment.

III. Contact Stabilization Plant Operating Costs (1972 Dollars)

Annual Power Costs (based on 87 connected HP) $ 11,397.00

It is estimated that 5 hours a day would be required for plant maintenance.

Estimated Chemical Costs (Chlorine) $2.75 per day.

ALTERNATE NO. 3

AERATED LAGOON PLANT

I. Design Conditions (Also see Design Conditions for Alternate No. 1)

Raw B.O.D. is 1685 pounds per day less 40% B.O.D. removal in the air flotation unit, leaving 1011 pounds per day B.O.D. in the primary effluent. Therefore, a B.O.D. removal of 93% is required through the remaining portion of the plant to meet the required effluent standards.

II. Anaerobic Lagoon Design

It is proposed to construct two anaerobic basins (lined with existing clay) and induce a load of 15 pounds per day of B.O.D. per 1000 cubic feet of tank space. It is assumed that a 50% B.O.D. reduction will oddur through these lagoons. Install two lagoons each 66 feet square by 15 feet deep.

III. Aerobic Lagoon Design

It is proposed to construct two lagoons lined with existing clay. Each lagoon shall be 300 feet square by 10 feet deep. Aeration in the proposed lagoons will be supplied by a subsurface method. The two lagoons will have a combined detention time of 40 days at design flow.

IV. Lagoon System Capital Costs (1972 Dollars)

Sub-Total (Add Air Flotation Cost) $200,663.50

No enclosure for above equipment.

V. Lagoon System Operating Costs (1972 Dollars)

Annual Power Cost (Based on an estimated 90 connected HP) $ 11,700.00

It is estimated that 3 hours a day would be required for plant maintenance.

Estimated Chemical Costs (Chlorine) $2.75 per day.

ALTERNATE NO. 4

AERATION BASIN PLANT

I. Design Conditions (Also see Design Conditions for Alternate No. 1)

Raw B.O.D. is 1685 pounds per day less 40% B.O.D. removal in the flotation unit, leaving 1011 pounds per day B.O.D. in the primary effluent. Therefore, a B.O.D. removal of 93% is required through the secondary portion of the plant to meet the required effluent standards.

II. Plant Capital Costs (1972 Dollars)

Sub-Total (Add Air Flotation Cost)	$122,427.80

No enclosure for above equipment.

III. Plant Annual Operating Costs (1972) Dollars)

Annual Power Costs (Based on Estimated 87 connected HP)	$ 11,397.00

It is estimated that 5 hours a day would be required for plant maintenance.

Estimated Chemical Cost (Chlorine) $2.75 per day.

EVALUATION OF VIBRATORY BLANCHER-COOLER FOR SNAP BEANS AND LIMA BEANS

John L. Bomben*, W. C. Dietrich*, J. S. Hudson*, E. L. Durkee*,
R. Rand**, J. W. Farquhar*** and D. F. Farkas*

INTRODUCTION

The Vibratory Blancher-Cooler resulted from research aimed at reducing the waste load from blanching and cooling and at improving the design and heat efficiency of steam blanchers. The pilot plant, whose design and performance is described here, combined a series of developments of the work done at the Western Regional Research Center on steam blanching and cooling vegetables prior to freezing. Each of these developments was tested to the small pilot plant stage, and the Vibratory Blancher-Cooler incorporated all of these developments into a prototype, which was large enough to demonstrate the suitability of these previously developed concepts for production use in a vegetable freezing plant.

The use of vibratory conveyors for steam blanching was developed to reduce the size and improve the heat efficiency of steam blanchers (2, 3). The spiral or stacked vibratory conveyor allowed for a more compact design than did the conventional belt conveyor in steam blanchers. In comparison to water blanchers, steam blanchers are large and have a low heat efficiency. The lower waste load of steam blanching (4) has not been sufficient in some cases to justify its use in place of water blanching, because for the same processing capacity steam blanchers are much larger and cost more than water blanchers. Until recently, little attention has been paid to heat efficiency, but the scarcity of energy should make this an important criterion now.

Using steam blancher condensate as a spray during air cooling was another development incorporated into the Vibratory Blancher-Cooler. This technique reduced the waste load of both blanching and cooling (2, 5). By using air, instead of flume cooling, the hydraulic waste load of cooling was reduced enormously, and the organic waste load produced by the leaching of solids in the flume was eliminated. By using the steam blancher condensate as a spray during air cooling, the waste load of blanching was elminated,

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*USDA, Western Regional Research Laboratory, Berkeley, California.
**California State University, Chico, California (employed by American Frozen Food Institute for the project).
***American Frozen Food Institute, Washington, DC.

and the waste load of both blanching and cooling was reduced to the unevaporated and unabsorbed liquid leaving the cooler.

The technique of Individual Quick Blanching (IQB) was included in the Vibratory Blancher-Cooler since it gave an additional means of reducing the size of the blancher. This heating and holding technique in addition gives a uniform blanching of vegetables and reduces the waste load of a steam blancher (1).

Pilot Plant Design

A schematic diagram of the pilot plant is shown in Figure 1, and a photograph of it, as it was installed at Patterson Frozen Foods (Patterson, California), is shown in Figure 2. The pilot plant occupied a floor area of 12 ft by 10-1/2 ft, and it had a height of 13 ft-11 in. It was constructed by the Vibrating Equipment Division of Rexnord Corporation, Louisville, Kentucky. The nominal design capacity was one ton per hour with a one pound per ft^2 conveyor loading. The pilot plant had a shipping weight of 19000 lbs. It consisted of the following units: heater, holder, cooler, air blower with filter, and condensate spray system.

The heater was a vibratory spiral enclosed in a double wall insulated (1 in. air spacing) housing having one access door (Figures 2 & 3). At the bottom of the housing there was a 2 in. diameter drain for condensate from the inside walls. The spiral conveyor, consisting of three 11-15/16 in. wide flights, had a 12 in. pitch. Steam was distributed through the central tube, which had 3/4 in holes 30 in. apart and 3 in. above the spiral conveying surface. The spiral and housing were made of stainless steel (Type 304, No. 2B finish on spiral and No. 3 finish on housing). There were two feed spouts; one was at the beginning of top flight and the other was at the beginning of the middle flight. Only the top feed spout was used in the experiments described here. Two 1-1/2 hp electrical motors (220V, 900 rpm), which had eccentric weights on their extended shafts and which were mounted at 45° to the horizontal, vibrated the spiral at a frequency of 890 cpm. The drive motor mounting was suspended with cables and springs to isolate the vibration from the structural framework. The amplitude of vibration could be varied from 0 to 3/8 in by shifting the position of the eccentric weights on the motors. The direction of the vibration moved the vegetables down the heater spiral, and the amplitude of vibration determined their conveying velocity.

The vegetables leaving the heating spiral dropped into the holder (Figures 2 and 3), which was a horizontally vibrating conveyor (5 ft long x 1 ft x 1 ft) enclosed by double wall insulation (1 in. air space). At the bottom of the holder near the feed end there was a 1 in. drain for the condensate produced by the vegetables on the heater spiral. A screen of perforated stainless steel was installed over the drain to prevent it from being plugged by vegetables. The holder had a 2° incline toward the feed end to drain liquid to the condensate pump. The holder was vibrated at 890 cpm by a 1-1/2 HP electrical motor (220 V; 900 rpm) with a doubly extended shaft on which two series of eccentric weights were mounted. By changing the number of weights the amplitude of vibration could be varied from 0 to 1/4

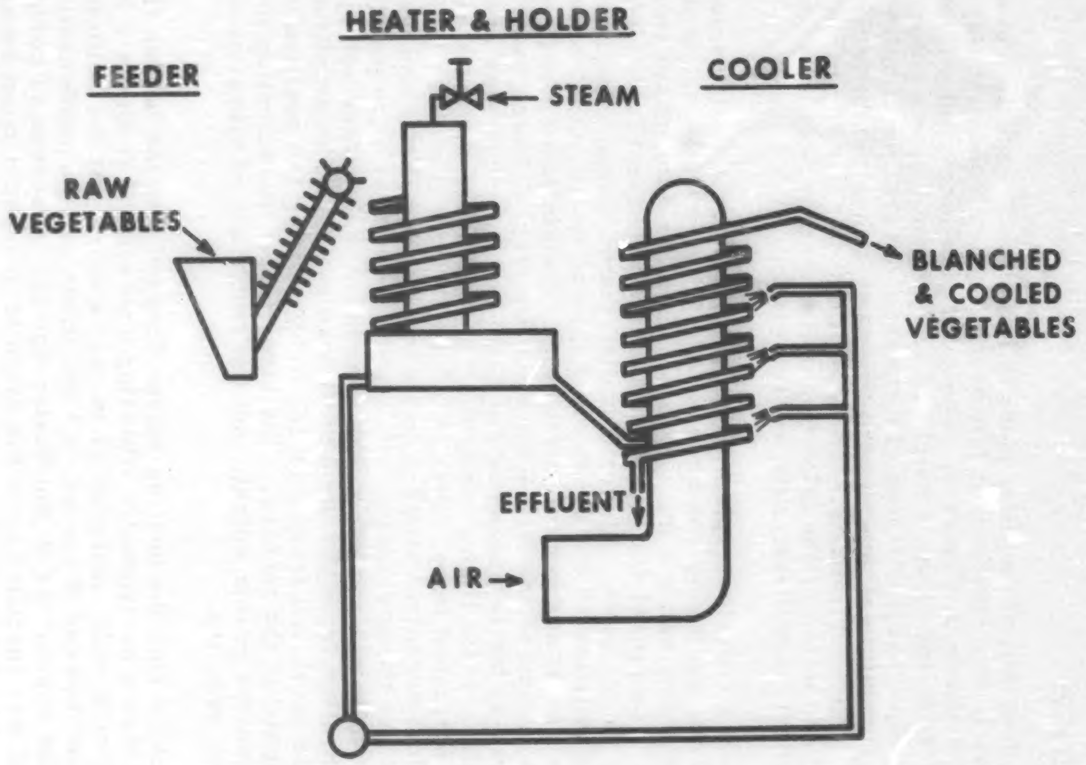
HEATER & HOLDER
FEEDER
STEAM
COOLER
RAW VEGETABLES
BLANCHED & COOLED VEGETABLES
EFFLUENT
AIR

Figure 1 - Schematic diagram of Vibratory Blancher-Cooler.

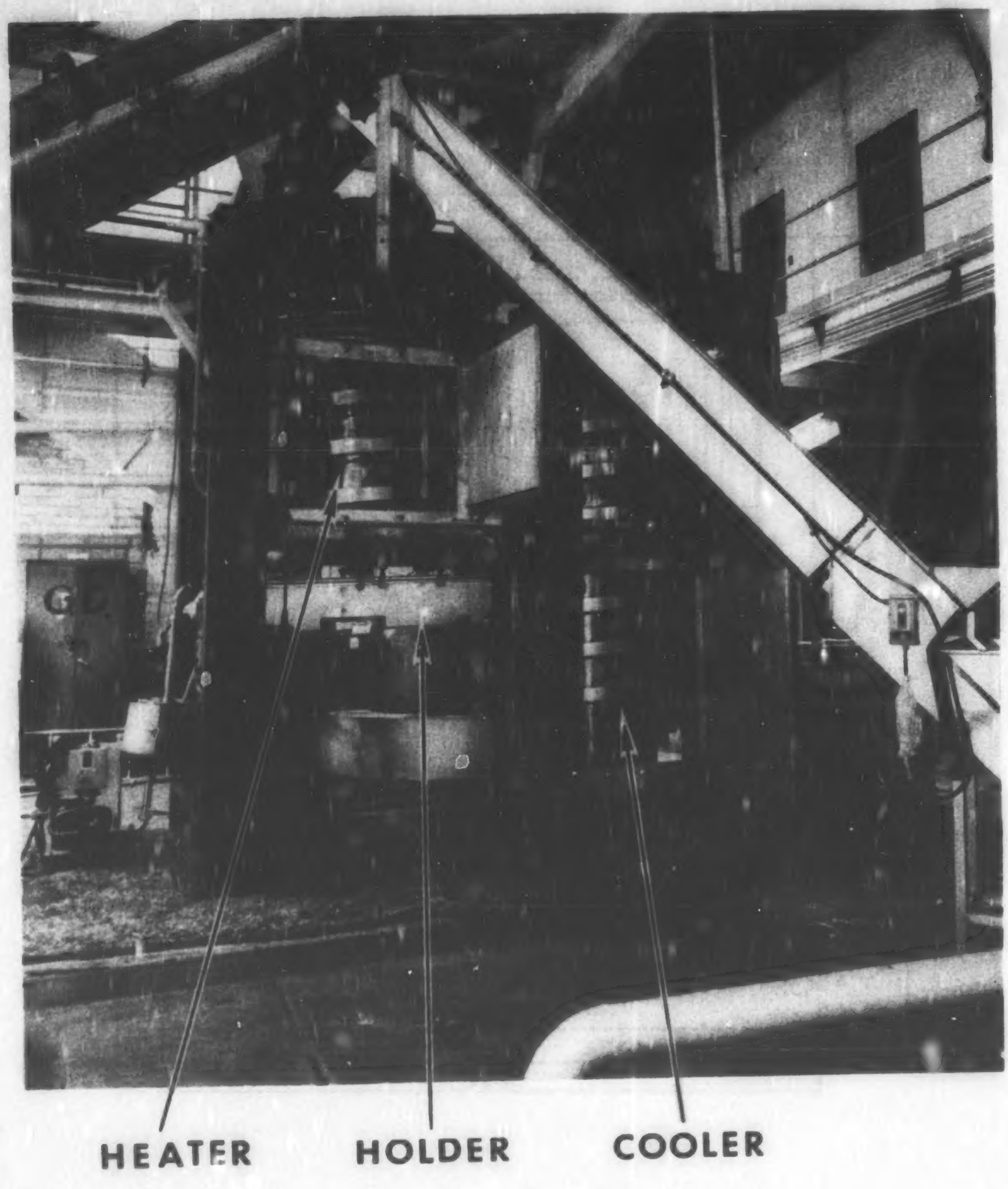
HEATER
HOLDER
COOLER

Figure 2 - Photograph of Vibratory Blancher-Cooler Pilot Plant.

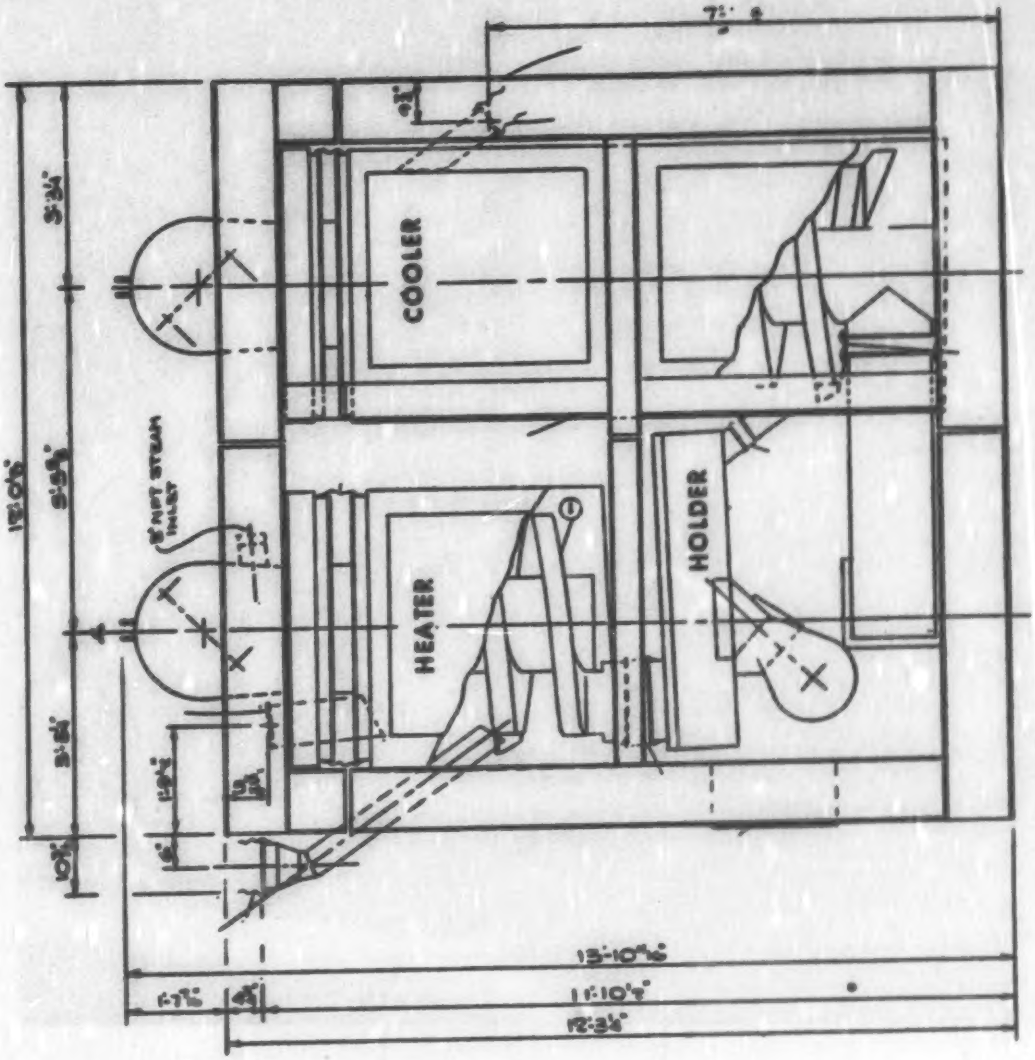
COOLER
HEATER
HOLDER
STEAM INLET

Figure 3 - Detailed drawing (elevation) of Vibratory Blancher-Cooler Pilot Plant.

in. In addition, the holder motor was equipped with a timer that controlled the period the motor was on and off to get a desired residence time. The vibration was isolated from the supporting framework by suspending the holder with cables and springs.

The blanched vegetables leaving the holder were discharged to the cooler, where the vegetables moved up the vibrating spiral conveyor. The cooler spiral conveyor (Figures 2 & 3) had the same design as the one in the heater except that it had 6-1/2 flights. The drive unit for the cooler was of the same design as that in the heater, but the motors were mounted so that the vibration in the cooler moved product up the spiral. Air was distributed over the product in the same way steam was distributed in the heater. The housing for the cooler was constructed of stainless steel (Type 304, No. 3 finish). It had two access doors and it had a 2" drain leading to an effluent collection tank.

The blower (Buffalo Forge, No. 40 MW) used for moving air over the product in the cooler had a rating of 5300 ft^3/min of 70° F air at 6 in. of water pressure. A filter (Continental No. 3P439M Side Access Conopac, 90% efficiency) was installed at the inlet of the blower. A damper on the outlet of the blower was used to control the amount of air flow.

The condensate spray system consisted of a pump (Waukesha Sanitary Pump, No. 10), approximately 15 ft of one inch diameter sanitary pipe and four nozzles (Spraying Systems Co., Unijet Nozzle No. 2503). Condensate was sprayed on the product in the cooler at the first, third, fifth and sixth flights. The condensate from the drain in the holder was filtered through three layers of cheesecloth to prevent particles from clogging the nozzles.

Temperatures at the inlet and outlet of the heater, holder and cooler were measured by thermocouples and recorded on a multi-point temperature recorder. A manometer measured the pressure at the blower, and the amount of air flow was determined from the blower performance curve supplied by the manufacturer. A rotameter (Fischer-Porter, Model No. 10A1152, 100% of scale = 199 scfm air), which had been calibrated by condensing and weighing the steam flowing through it, was used to measure the flow of steam to the heater. Condensate was removed from the steam supply by passing it through a purifier (V. D. Anderson Co., Model LC-150). A pressure regulator (Spence Engineering Co., 3/4 in Type ED) maintained a constant pressure at the throttling valve installed in the steam line after the rotometer. The relative humidity of the air at the inlet of the filter was measured with an electronic humidity indicator (Humi-Chek, Beckman Instruments). A hot wire anemometer (Alnor, Thermo-anemometer) was used to measure the air velocity over the product in the cooler.

Experimental Runs

Raw vegetables for runs were collected into bins (4 ft x 4 ft x 4 ft) from the production line at the stage where they were ready for blanching. The snap beans (Galagreen variety) used in the pilot plant were collected at the point in the production line where they were washed, sorted and cut to 3/4 in lengths. Lima beans (Kingston, S4 and Bridgeton varieties) were collected after they had been washed and flotation graded in a 13-14% brine solution in the production line. Because the final rod-reel washer and the water blanchers were so closely connected in the production line, it was not possible to collect the lima beans for the pilot plant runs as thoroughly cleaned and washed as they were for the production line blanchers. In some cases it was necessary to collect beans as they left the brine sorter without any subsequent washing; other times it was possible to collect the lima beans after only a brief washing following the brine separator.

The testing of the pilot plant was done with three kinds of experimental runs: preliminary, batch and continuous. Preliminary runs were used to establish the feed rate, blanching time and cooling time and to observe the operating characteristics of the pilot plant for each vegetable. Each batch run consisted of blanching and cooling approximatey 2,000 lbs of raw vegetables and determining the yield of blanched-cooled vegetables, the solids lost from the raw vegetables and the waste load. In the continuous runs the pilot plant was operated for a longer time than the batch runs; the same quantities as in the batch runs were measured, but in addition samples were taken for microbiological analysis and sensory evaluation. Since the pilot plant was not installed soon enough, there was no time for continuous runs with snap beans.

Residence times in the heater, holder and cooler and the flow rates of steam and air were varied in the preliminary runs to determine the best conditions for processing the vegetables. Product velocities on the conveyors were measured by bundling approximately 200 g of vegetables in cheesecloth and timing their passage on the conveyors. With the steam to the heater off, preliminary runs were also used to observe the product flow on all the vibratory conveyors. With the steam to the heater on, the vegetables leaving the cooler were tested for peroxidase (6), and their temperature was measured. If the peroxidase test was negative and the product temperature was between 80 to 90°F, no further adjustments were made, and the series of batch and continuous runs were begun, using the conditions established in the preliminary runs.

For the batch runs one bin of raw vegetables was weighed and dumped into the feeder-elevator. After the temperature in the heater reached 212°F, the vegetables were started through the pilot plant. Samples (150 g) of raw vegetables and of vegetables leaving the cooler were taken every fifteen minutes. In the snap bean runs a 1.5 kg sample for sensory testing and chemical analysis was taken from the pilot plant and production line since there were no continuous runs. The vegetables leaving the cooler were analyzed for peroxidase several times during the run. About every 15 minutes a 500 g sample of product leaving the cooler was collected into a beaker, and the average temperature was measured with a dial thermometer. All the vegetables leaving the cooler were collected into a bin and weighed. All the cooler effluent was collected from the start of the run to the time when the vegetables were no longer being discharged from the holder. The effluent was weighed, and three 500 g samples were taken in polyethylene bottles.

For the continuous runs with lima beans essentially the same procedure as used in the batch runs was repeated, except that two to four bins (4000-8000 lbs) of raw vegetables were fed to the pilot plant giving runs from 2 to 5.5

hours. Samples (150 g) of raw vegetables and those coming from the cooler, as well as the temperature of those coming from the cooler, were taken every hour. Every hour, samples (50-100 g) for Total Aerobic Count and samples (1.5 kg) for sensory evaluation and chemical analyses were taken of the vegetables leaving the cooler. For comparison, 1.5 kg samples of blanched and cooled vegetables were also taken every hour from the production line. All vegetable samples were immediately frozen. The 1.5 kg samples were later made into a single composite. The blanched and cooled vegetables were collected into bins and weighed. The effluent was collected and weighed about every hour, and from this quantity a 9 kg composite sample was taken with the remainder being discarded. From the composite, three 500 g samples were taken in polyethylene bottles.

A series of analyses were done on the samples of the raw vegetables, blanched and cooled vegetables, and effluent. One sample bottle of effluent, taken as described above for each run, was refrigerated at 34°F and a Suspended Solids (SS) (7) analysis was done within 24 hr; analyses of Total Solids (TS) and Total Organic Carbon (TOC) (8) were done on this refrigerated sample within a week of the time of the run. Another sample bottle of effluent was frozen, and after about one month it was given to a water analysis laboratory (R. W. Hawksley Co., Richmond, California) for analysis of Biological Oxygen Demand (BOD). A spare sample bottle of effluent was kept frozen for checking any results that were questionable. All vegetable samples were taken in polyethylene bags. The 150 g samples of raw and blanched-cooled vegetables were kept frozen and they were analyzed for Total Solids (9) within two months of the run. The 50-100 g samples taken for Total Aerobic Count were kept at -20°F (for less than one month) until they were analyzed (10). The composites of 1.5 kg samples were also stored at -20°F; part (50-100 g) of the composite was used for analysis of peroxidase, ascorbic acid and chlorophyll conversion (6) while the remainder was used for sensory evaluation by the Duo-Trio test (11) within 3 months of the run.

The operating conditions of lima bean blanchers and coolers in the production line were also measured. The blanchers in the production line were screw conveyor water blanchers. Cooling was done by either a combination of air and flume or only flume. The feed rate of vegetables and effluent discharge rate were measured by collecting and weighing all vegetables going into the blancher or all the effluent leaving the blancher or cooler for short periods of time (0.25 or 0.5 min). Samples of raw vegetables (150g), blanched-cooled vegetables (150 g), and blancher and cooler effluents (500g) were taken for each measurement. The effluent samples were analyzed for TS, TOC and BOD, and the lima bean samples were analyzed for TS.

Operating Conditions

The operating conditions used for the nine batch and five continuous runs made with the pilot plant and the data measured on the lima bean production line are shown in Table 1.

The residence time for lima beans in the heater and holder were slightly longer than for snap beans (Table 1) at the same vibration amplitude;

TABLE 1. OPERATING CONDITIONS

Run Number & Vegetable Variety	Run Time (min)	Feed Rate (lb/hr)	Heating Time (min)	Holding Time (min)	Holder Temp (°F)	Steam Flow (lb/hr)	Cooler(e, f, g) Vegetable Temp (°F)
			PILOT PLANT				
Snap Beans							
SB-1 Galagreen	45	2220	1.0(a)	1.0(b)	164±20	(i)	86
SB-2 Galagreen	50	2160	1.0(a)	1.0(b)	185±5	285	90
SB-3 Galagreen	49	2110	1.0(a)	1.0(b)	186±10	285	88
			PILOT PLANT				
Lima Beans							
LB-1 Kingston	45	2750	1.1(a)	1.3(b)	186±3	285	89
LB-2 Bridgeton	35	1230	1.1(a)	3.5(c)	209	197	76
LB-3 S4	78	1200	1.1(a)	1.3(b)	209	197	75±2
LB-4 Kingston	83	2590	1.1(a)	1.3(b)	---	225	73±1
LB-5 S4	50	2700	1.1(a)	1.3(b)	196±10	285	80±1
LB-6 Bridgeton	57	2500	1.1(a)	1.3(b)	---	328	77±1
LB-7 Kingston	126	1940	1.1(a)	1.3(b)	195±10	242	84±2
LB-8 Kingston	149	1850	1.1(a)	2.5(d)	197±6	242	83±2
LB-9 Bridgeton	272	1850	1.1(a)	2.5(d)	199±6	242	83±3
LB-10 Bridgeton	331	1550	1.1(a)	2.5(d)	200±5	235	79±4
LB-11 Kingston	274	1640	1.1(a)	2.5(d)	195±5	240	83±3
			PRODUCTION LINE				
Lima Beans							
LBP-1 Kingston		9280	4.5(h)			(j)	88(k)
LBP-2 Kingston		6580	4.5(h)				109±1(l)
LBP-3 Kingston		12400	4.5(h)				103±3(m)

(a) Vibration amplitude = 3/16 in.
(b) Vibration amplitude = 1/8 in; on continuously.
(c) Vibration amplitude = 1/8 in; on 5 sec., off 10 sec.
(d) Vibration amplitude = 1/8 in; on 10 sec., off 10 sec.
(e) Cooler residence time = 2.9 min.; vibration amplitude = 1/4" for SB 1-3
(f) Cooler residence time = 4.8 min.; vibration amplitude = 1/4" for LB 1-8.
(g) Cooler residence time = variable, vibration amplitude = 1/4" for LB 9-11.
(h) Blancher temp. = 210°F.
(i) Steam flow was erratic since this was first run done with the pilot plant.
(j) There was no measuring device for steam flow on the production line blanchers.
(k) Cooling time: 0.7 min in air with water sprays and 0.2 min in water flume.
(l) Cooling time: 0.3 min in water flume.
(m) Cooling time: same as (k)

otherwise both vegetables gave reproducible residence times, and they flowed uniformly down the conveyor spiral. The amplitude of vibration in the holder was kept at 1/8 in., and the residence time was controlled by the timer. In the cooler the conveying velocity for lima beans was much slower than for snap beans, and the flow was nonuniform at times.

The steam flow was adjusted to maintain a temperature of 190°F in the holder. The heater was always kept at 212°F.

Condensate from the heater was pumped immediately to the nozzles in the cooler. Its total residence time from discharge from the holder to the nozzles was calculated to be less than 1.5 min. Although no difficulty was experienced in spraying the snap bean condensate, the lima bean condensate sometimes plugged up the nozzles. The unevaporated and unabsorbed condensate in the cooler drained down the outer edge of the conveyor surface to the effluent collection tank.

The air flow was highly turbulent in the cooler and only an average velocity could be estimated. An air flow of approximately 3500 cfm was used for most of the runs, and this gave an average velocity of 300 ft/min over the vegetables in the cooler. The wet bulb temperature of the air entering the filter was 55-60°F for most of the runs.

Waste Load and Product Quality Results

Table 2 shows the product yield, solids loss and the liquid waste load obtained for all the experimental runs. The yield is the weight of blanched and cooled vegetables when compared to the weight of raw vegetables: % yield = 100 x (weight of blanched cooled vegetables)/(weight of raw vegetables). The solids loss measures the solids which are leached from the vegetables in blanching and cooling when compared to the amount of solids originally present in the raw vegetables: % solids loss = 100 x (hydraulic load) x (TS in effluent)/(TS in raw vegetable). The other quantities in Table 2 (hydraulic load, BOD, TOC, SS) are calculated from the feed rate, effluent rate and analyses of the effluent, and they are reported on the basis of 1,000 lb of raw vegetables.

Table 3 gives the results of sensory comparisons (Duo-Trio) of product from the pilot plant with that of the production line. The results are reported as the number of judgements (% correct) correctly identifying the sample that was identical to the control. The control for a comparison could be either the pilot plant or production line sample. Judges were also asked to state which sample they preferred. Probabilities are from the Binomial Probability Table.

Table 4 summarizes the results of the analyses for total solids, peroxidase, ascorbic acid and chlorophyll conversion of pilot plant and production line samples. The results are averages of 2 or 3 determinations done on 50 to 100 g of vegetables. The data on ascorbic acid are reported without accounting for differences in moisture content between the vegetables of the production line and those of the pilot plant.

TABLE 2. PRODUCT YIELD, SOLIDS LOSS AND LIQUID WASTE LOAD

Run Number	Product Yield (%)	Product Solids Loss (%)	Hydraulic Load (lb/1000 lb)	BOD (lb/1000 lb)	TOC (lb/1000 lb)	SS (lb/1000 lb)
PILOT PLANT						
SB-1	86.5	--	51.4	0.802	0.617	--
SB-2	98.5	0.709	32.1	0.520	0.313	0.0369
SB-3	97.2	0.707	29.3	0.439	0.289	0.0440
LB-1	89.2	0.704	47.1	0.885	0.674	0.503
LB-2	83.2	--	41.7	0.651	0.575	0.216
LB-3	90.9	--	39.0	0.772	0.536	0.423
LB-4	94.1	0.494	28.3	0.832	0.514	0.403
LB-5	92.1	0.0516	4.63	0.0982	0.0637	0.0411
LB-6	--	0.154	7.89	--	0.159	0.137
LB-7	--	0.202	11.3	--	0.200	0.167
LB-8	93.2	0.372	19.6	--	0.387	0.347
LB-9	92.9	0.148	8.19	0.236	0.150	0.122
LB-10	92.1	0.794	40.1	0.794	0.992	--
LB-11	92.0	1.22	60.2	1.87	1.51	1.80
PRODUCTION LINE						
LBP-1	(a)	1.69(B) 0.515 (C)	548 (B) 536 (C)	3.18 (B) 0.911 (C)	1.78(B) 0.379 (C)	0.849 (B) 0.150 (B)
LBP-2		1.61 (B) 1.20 (C)	460 (B) 780 (C)	3.77 (B) 1.03 (C)	1.69 (B) 0.409 (B)	0.846 (B) 0.150 (C)
LBP-3		1.62 (B) 0.480 (C)	373 (B) 313 (C)	3.17 (B) 1.00 (C)	1.75 (B) 0.438 (C)	0.683 (B) 0.121 (C)

Hydraulic load, BOD, TOC, and SS are reported per 1000 lb of raw vegetable.

(B) refers to blanching.

(C) refers to cooling.

(a) Yield could not be accurately measured in the production line.

TABLE 3. SENSORY EVALUATION OF PRODUCT BY DUO-TRIO TEST

Run Number	Total Number of Judgments	% Correct	% Preference for Pilot Plant Sample
SB-1	36	61	42
SB-2	36	61	44
SB-3	34	53	68
LB-7	41	66*	54
LB-8	40	65*	67*
LB-9	41	80**	63
LB-10	38	63	32*
LB-11	40	63	55

NS = Not Significant.

*Probability 0.05

**Probability 0.01

TABLE 4. ANALYSIS OF VEGETABLES

Run No.	Raw TS (%)	Product TS Pilot Plant (%)	Product TS Prod. Line (%)	Yield (%)	Solids Loss (%)	Residual Peroxidase Pilot Plant (%)	Residual Peroxidase Prod. Line (%)	Ascorbic Acid Pilot Plant mg/100g	Ascorbic Acid Prod. Line mg/100g	Chlorophyll Conversion Pilot Plant (%)	Chlorophyll Conversion Prod. Line (%)
SB-1	10.76	11.20	10.35	86.5	--	2.1	1.6	14.1	13.9	16.8	16.8
SB-2	10.75	10.75	--	98.5	0.709	1.1	0.5	15.1	13.4	13.8	14.1
SB-3	10.75	10.40	--	97.2	0.707	1.5	0.5	14.1	13.4	13.8	14.1
LB-1	36.12	37.66	--	89.2	0.704						
LB-2	--	--	--	83.2	--						
LB-3	--	41.37	--	90.9	--						
LB-4	41.29	39.93	--	94.1	0.494						
LB-5	40.65	41.71	34.60	92.1	0.052	0.0	0.0	18.7	16.7	13.0	14.5
LB-6	38.46	39.32	--	--	0.154	--	--	--	--	--	--
LB-7	40.86	39.74	36.49	--	0.202	0.0	0.0	26.7	23.8	11.9	13.9
LB-8	40.72	40.13	36.01	93.2	0.372	0.0	0.0	27.2	24.0	17.2	10.8
LB-9	41.60	40.71	38.03	92.9	0.148	0.0	0.0	20.6	19.7	15.6	13.0
LB-10	35.92	35.62	34.80	92.1	0.794	0.0	0.0	19.1	20.3	19.1	11.3
LB-11	36.09	36.07	34.82	92.0	1.22	0.0	0.0	24.6	25.2	18.9	8.0
LBP-1	36.08		35.81	--	2.21						
LBP-2	35.35		34.15	--	2.81						
LPB-3	35.37		35.32	--	2.10						

Ascorbic acid analyses were not corrected for differences in the amount of water in the vegetables.

Figure 4 gives the results of the Total Aerobic Count on the continuous runs of lima beans. Since there were only batch runs for snap beans, no microbiological analysis was done for that vegetable.

Discussion of Pilot Plant Design and Operation

The pilot plant makes a large reduction in hydraulic waste load and organic waste load when compared to the conventional processing simulated in previous work or when compared to the conventional processing of lima beans as measured on the production line in this work. The effluent leaving the cooler is a low volume highly concentrated waste stream: 16000 ppm BOD for snap beans and 16000-29000 ppm BOD for lima beans. A waste stream of this concentration would be much less expensive to treat than the high volume, low concentration waste stream typical of the present blanching and cooling systems. The product yield and waste load obtained in the pilot plant (Table 2) are similar to those of the previous small scale experiments for snap beans and lima beans (5). Table 5 compares the results of the previous work with the range of results obtained in this work.

The floor space required by the pilot plant was low when compared to a conventional steam blancher of the same capacity. The conveying length of the heater spiral was 25 ft. Since vegetables could pile up in the holder, its length was only 5 ft. and it provided residence times equal to (snap beans) or twice (lima beans) the times in the heater. If a single layer belt loading of 1 lb/ft^2 is assumed, a belt steam blancher of conventional design would have to be 50 ft. long and 1 ft. wide for snap beans and 75 ft. long and 1 ft. wide for lima beans to provide the same conveying capacity and blanching times as the pilot plant. Since the floor area taken by the heater and holder was approximately 20 ft^2 (5 ft. x 4 ft.), the entire blancher of the pilot plant would occupy 1/2 to 1/3 the space of the 50-75 ft^2 area taken up by the equivalent conveyor belt of a conventional steam blancher, excluding the housing and supporting framework.

The heat efficiency of the pilot plant blancher was very high when compared to existing steam blanchers. A nylon chute was used for feeding the raw vegetables to the first flight of the heater. When the chute was filled with vegetables, it formed a seal, and when it was empty it collapsed allowing very little steam leakage. The discharge end of the heater led directly into the holder, whose discharge was sealed by a canvas chute. This elimination of steam leaks and the insulation of the exposed surfaces combined to give the blancher an efficiency as high as 85-90%, which was calculated by comparing the steam measured by the rotameter to that calculated to be necessary to give the vegetables an average temperature of 190°F (5). Steam blanchers with water-sealed ends report efficiencies of 25% (12), and blanchers without seals would be even less.

The Total Aerobic Count of the samples taken from the pilot plant was very low when compared to the acceptable limit of less than 500,000 colonies per gram for frozen vegetables given by Sharf (10) or to the count of product taken from the production line (1000-2000 colonies/g). There was no increase in microbial count with time of pilot plant operation for a period of over five hours (Figure 4), demonstrating that the cooler did not have

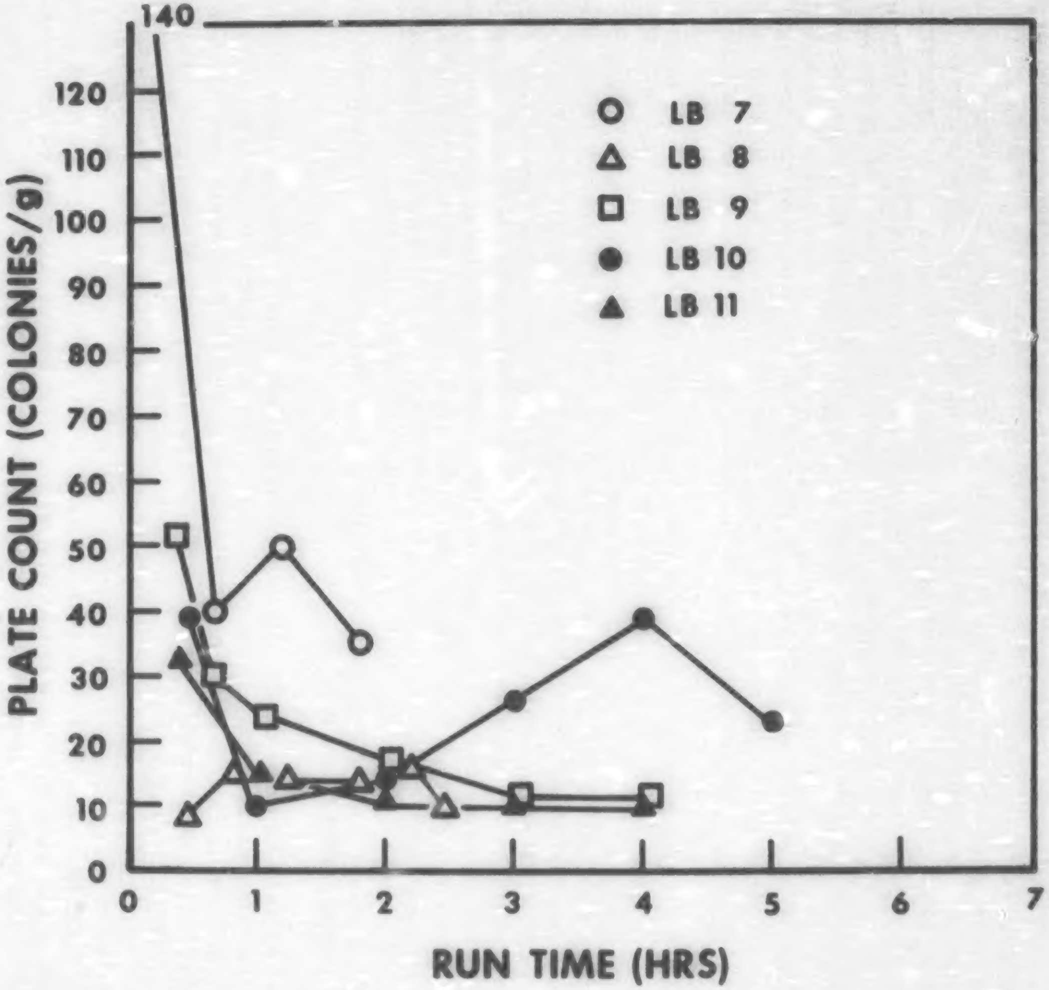

Figure 4 - Total Aerobic Plant Counts on Continous Runs with Lima Beans

TABLE 5. COMPARISON OF PILOT PLANT WITH PREVIOUS WORK AND PRODUCTION LINE

	Yield (%)	Solids Loss (%)	Effluent (lb/1000 lb)	TOC (lb/1000 lb)
Snap Beans				
Vibratory Blancher-Cooler Pilot Plant	86.5-97.2	0.71	29-51	0.29-0.62
Previous Work: Steam Blanch & Air Cool w/Condens. (5)	92.0	1.1	50	0.37
Previous Work: Steam Blanch & Water Cool (5)	94.3	3.9	5080	1.5
Lima Beans				
Vibratory Blancher-Cooler Pilot Plant	89.2-94.1	0.052-1.2	46-60	0.06-1.5
Prevous Work: Steam Blanch & Air Cool w/Condens. (5)	93.9	0.38	40	0.60
Previous Work: Steam Blanch & Water Cool (5)	100.6	1.5	5070	2.8
Production Line: Water Blanch & Air-Water Cool	---	2.1-2.8	690-2200	2.1-2.2

Previous work is described in reference (5).

areas promoting microbial growth. The samples of product taken from the production line were taken just prior to freezing, and so their higher microbial counts were probably due to the fact that the vegetables had been exposed to the plant environment on the inspection belts; whereas, the product from the pilot plant had no such exposure.

The sensory evaluation of the blanched and cooled product showed that there was essentially no difference in the appearance, taste or texture of the product due to processing in the pilot plant as compared to processing in the production line. Some of the small differences (Table 3), found in the lima beans were probably due to differences in saltiness because the raw vegetables for the pilot plant could not be collected after the final wash in the production line. Preferences of the panel were not consistent and alternated between lima beans produced in the pilot plant and those taken from the production line (Table 3).

The solids loss (Tables 2, 4 and 5) is a measure of the amount of nutrient lost by leaching from the vegetables. Although the vegetables processed in the pilot plant had lower solids losses than those taken from the production line (Tables 2 and 4) or those processed by a simulated conventional process (Table 5), the differences in ascorbic acid did not necessarily correlate with those in solids loss. Generally, the ascorbic acid content was not much different when samples taken from the production line were compared to those of the pilot plant. The slightly higher ascorbic acid of the snap beans processed in the pilot plant could be accounted for entirely by the water evaporated in air cooling; similarly, the differences in ascorbic acid for the lima beans of runs LB 5, 7 and 8 could be accounted for by differences in the amount of evaporation.

Ascorbic acid is lost both by leaching and thermal degradation, but chlorophyll conversion is solely a measure of thermal degradation. Since the cooler conveying velocity was much slower in runs LB 10 and 11 (Table 1), owing to conditions described later, the heavily loaded conveyor gave an excessively slow cooling rate. The slower cooling rate was responsible for the higher chlorophyll conversions, as compared to those of the production line, found in lima beans processed in these pilot plant runs In those runs (LB 5 and 7) where the cooler conveying velocity was faster, there was essentially no difference in chlorophyll conversion between pilot plant and production line. In contrast, the snap beans showed no tendency to have a higher chlorophyll conversion in the pilot plant runs. The faster conveying velocity of the snap beans gave less of a conveyor loading and thus rapid cooling.

The large variation in solids loss, hydraulic waste load, TOC, BOD and SS shown in Table 2 for the pilot plant runs with lima beans appeared to result from variations in the maturity of the raw beans used. Comparison of Tables 2 & 4 shows that the lower waste loads (LB 5, 6, 7, 8 and 9) were measured when the raw beans had a high TS (dry, mature beans) and the higher waste loads (LB 10 and 11) were measured when the TS of the raw lima beans was relatively low. The drier beans probably absorbed more of the condensate in the heater and cooler (13).

The pilot plant was designed to blanch and cool 2000 lb/hr. Because it was not installed soon enough in the season, it was not possible to test the maximum capacity for snap beans. The conveyors did not appear to be fully loaded at the feed rate used (2200 lb/hr) with snap beans, and a higher feed rate appeared to be possible. Since lima beans are generally blanched for longer times than snap beans, and since, at the same amplitude of vibration, the lima beans conveyed more slowly than did the snap beans, the pilot plant should have a lower capacity for lima beans than snap beans. The 2500-2750 lb/hr feed rates in runs LB 1, 4, 5 and 6 were easily conveyed by the heater and holder, but they exceeded the capacity of the cooler. Thus, the continuous runs had to be made with lower feed rates (Table 1).

Lima beans were not conveyed up the cooling spiral as well as the snap beans. Under some conditions the conveying velocity steadily decreased until after about one hour of operation the lima beans stopped moving altogether. Increasing the stroke of the conveyor to the maximum 3/8 in. stroke did not convey them faster, but it did make their flow erratic, giving a circulation pattern--lima beans on the outer edge were conveyed very rapidly and those in the center slowly or not at all, and as the average conveying velocity decreased, the lima beans in the center moved downward in the opposite direction to those on the outer edge. If the conveyor was washed clean of fragments, leaves and stems, which had stuck to the conveyor surface, the lima beans moved again with their initial conveying velocity. This conveying problem in the cooler occurred sooner in those runs where there were more leaves, stems and bean fragments in the raw lima beans, a condition aggravated by the inability to get completely cleaned and washed beans from the production line. In those cases where the raw lima beans were clean, even after only a preliminary wash, they were continuously conveyed by the cooler, processing over 8,500 lbs in Run LB 10. Since the lima beans showed uniform, steady flow in the heating spiral, arranging the equipment so that lima beans flowed down the cooling spiral would give better control of the cooling time.

Preliminary runs were tried with Brussels sprouts, broccoli and cauliflower. Although it was not possible to convey these blanched vegetables up the cooler, they were conveyed down the heating spiral evenly and with reliable residence times. Thus, it appears that the cooler could operate satisfactorily if it were arranged to convey downward. This arrangement would also give lima beans a faster conveying velocity in the cooler thereby giving better cooling conditions. In the pilot plant this would require raising the discharge of the holder by 5 ft. and thus making the top of the heater assembly a total of 19 ft. from the floor.

The advantages of reduction in waste load and solids loss from the vegetables cannot be achieved economically by using air cooling because frozen vegetables are marketed by total weight. Under these marketing conditions the evaporation in the cooler translates into a loss of product, which cannot be balanced by the savings in steam and effluent disposal costs (2). For lima beans, where brine sorting follows cooling, the loss of weight is probably regained by soaking in the brine; however, this regaining of weight is at the expense of the solids leached from the vegetables in the brine solution in the same way as flume cooling. The full advantages of air cooling for liquid waste reduction can be achieved only if frozen vegetables are marketed by some standard other than total weight.

No estimate of the capital cost of a full size blancher-cooler has been made based on the pilot plant. The pilot plant cost $61,500. Since the cost required for installation of the plant would vary considerably, depending on location, it is difficult to establish that amount, but as a guide the installation cost of the pilot plant was about 10% of the equipment cost. Since most conventional steam blanchers are custom-built there is no established cost with which to compare.

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Reference to a company or product names does not imply approval or recommendation of this product by the U.S. Department of Agriculture to the exclusion of others which may also be suitable.

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TREATMENT OF MEATPACKING PLANT WASTEWATER BY LAND APPLICATION

By

Anthony J. Tarquin

INTRODUCTION

The application of municipal and industrial wastewaters to land for treatment and or disposal is not new. A textbook on wastewater treatment which was published in 1903 contained complete chapters on sewage irrigation and sewage farming (1). The land application method of wastewater treatment has been demonstrated not only in the United States, but in many foreign countries as well. Liquid wastes with a wide spectrum of physical and chemical characteristics have been treated successfully by soil application, including municipal sewage, cannery wastes, pulp and paper mill wastes, dairy wastes, vegetable and food processing wastes, wood distillation wastes, poultry wastes, and many others (2, 3).

With the constant annual increase in per capita consumption of beef and meat products, the need for technological advances in the treatment of meatpacking wastes has never been greater.

In 1967, the potential daily BOD from the slaughterhouse and meatpacking industry was estimated at 2.17 million pounds or a population equivalent of 13 million people (4). The U.S. Department of Agriculture places the meatpacking industry second to only the Pulp and Paper Industry in terms of potential five day Biochemical Oxygen Demand pollution. In the food and kindred products industry, meatpacking ranks first in daily pollutional discharge.

Interest in the land application method of wastewater treatment for meatpacking plant wastes has been stimulated by recent federal regulations requiring a greater degree of wastewater treatment. Of particular importance in this regard is the increased emphasis that is being placed on residual carbon, nitrogen and phosphorous removal. Some land application systems have effectively removed almost all of the carbon and phosphorous and, under controlled operating conditions, a large percentage of the nitrogen. In addition to the high degree of waste treatment which is achieved, of course, some of the valuable plant nutrients are recovered in the process. The purpose of this report is to present the experiences gained during pilot scale treatment of meatpacking plant wastewater by land application. Most of the results reported herein were obtained from pilot studies at the Peyton Meatpacking plant located in El Paso, Texas.

TYPES OF LAND APPLICATION SYSTEMS

There are three general types of land application systems as follows: irrigation, overland flow, and infiltration-percolation. All three types can be used for treating meatpacking plant wastewater, depending on the topography, wastewater strength, soil type, etc.

Irrigation refers to the use of the wastewater for the primary purpose of growing crops. Accordingly, the hydraulic application rates are rather low (i.e., less than 4 inches per week) and the wastewater quality is usually equivalent to secondary effluent. Since meatpacking plant wastes frequently have very high nitrogen concentrations, the nitrogen loading rate must be controlled if nitrogen build-up and/or ground water contamination are to be avoided. For this reason, crops having high nitrogen uptakes are usually preferred.

Overland flow, as the name implies, involves application of the wastewater to a sloping area (2-6% slope) with subsequent collection and final disposal of the effluent. This method is used on clay-containing impervious soils or where topography precludes the use of one of the other methods.

Infiltration involves percolation of the wastewater into the groundwater. Hydraulic loading rates for these systems range from a few inches per week to several feet per week, depending on the quality of wastewater applied. Loamy or sandy soils are preferred for infiltration-type land application systems.

WASTEWATER CHARACTERISTICS

Most meatpacking plant wastes are quite strong when compared to domestic wastewater strength. Table 1 shows the effluent concentrations from the catch basin of the Peyton Packing Plant.

Table 1. CATCH BASIN EFFLUENT CHARACTERISTICS

Parameter	Effluent Conc, mg/l ab	Range, mg/l
pH	7.3	6.6 - 8.1
BOD	2600	200 - 15,150
COD	5300	350 - 38,890
Grease	1280	110 - 8,165
Phosphorus	17	3 - 35
Kjeldahl - N	110	19 - 680
Total solids	3,450	540 - 13,975
Suspended solids	1,600	15 - 10,350

a. Avg. obtained from flow proportional composite
b. Except pH

The high concentrations for the values shown in the Table are typical of a packing plant effluent from the catch basin. When other types of treatment systems are employed, such as oxidation ponds, dissolved air flotation, or biological treatment systems, the strength of the waste is lowered considerably. However, when only a catch basin is used for wastewater treatment, the high nitrogen concentration is particularly troublesome for land application systems because of the close control required in order to achieve a high degree of nitrogen removal.

SITE CHARACTERISTICS

The characteristics of the treatment site determine, to a large extent, the type of land application system which should be designed. Some of the characteristics which must be taken into consideration in the design of a land application system follow.

Climate

The climate is one of the most important factors to consider when designing a land application system. Perhaps the most favorable climate from the standpoint of system operation is that of the Southwestern United States. Mild winters and arid conditions are very desirable characteristics because of the minimum holding facilities required. In the northern areas of the U.S., ponds capable of holding up to six months' flow must be included in the design of the land application system. Similarly, where large amounts of rainfall are common, some type of ponding area would be required for storage of the wastewater during rainy periods. These problems are not insurmountable but do add to the land requirements of the treatment system.

Soil

The type of soil at the treatment site determines, to a large extent, the kind of land application system which must be used. Soils containing even small amounts of clay are not well suited for infiltration systems because of the unfavorable sodium adsorption ratio of most meatpacking plant wastewaters. The sodium has a sealing effect on the soil which can reduce the infiltration rate considerably. Overland flow systems are preferred in clayey soils, therefore. On the other hand, the use of infiltration systems is favored on sandy soils. This is because the high strength of most meatpacking plant wastes requires low hydraulic loadings with uniform distribution. This is best achieved through high or low pressure sprinkler application on relatively flat land. The unfavorable sodium adsorption ratio of most packing plant wastewaters also becomes less significant when sandy soils are available.

Topography

The topography influences the type of system selected primarily because of the initial investment cost. Unless the soil contains clay, areas which are mainly flat favor infiltration systems while areas which have rolling hills favor overland flow. On the other hand, it is possible to create an overland flow area from land which is flat when soil conditions dictate such a system. A slope as shallow as 1-1/2% has been used in order to minimize earthmoving costs. Normal overland flow slopes range from 2-6%.

Groundwater

The quality of the groundwater in the vicinity of the treatment area will have a major influence on the type of system constructed. Where high quality groundwaters are prevelant, infiltration-type systems for meatpacking plant wastewaters are not highly recommended because of the likelihood of groundwater deterioration. Even with close system management, a considerable amount of nitrogen could be expected to reach the groundwater in infiltration systems. Additionally, most meatpacking plant wastewaters are extremely high in total dissolved solids, creating further potential problems where potable groundwaters are nearby. Thus, when the groundwater quality is high, infiltration systems for most meatpacking plant wastewaters are not too feasible.

Vegetation

In all types of land application systems, some type of soil cover is preferable. For infiltration systems, the vegetation helps maintain the infiltration rate and prevents compaction of the soil during sprinkler application. For overland flow systems, vegetation prevents channeling and soil erosion and enhances the establishment of the mulchy layer at the air-soil interface.

The kind of vegetation which is selected should ideally possess the following characteristics: long-growing season, high nutrient uptake, high moisture tolerance, high salt tolerance, and non-leguminous. Some grasses which have worked well in high strength wastewater land application systems are Reed Canary, Kentucky Tall Fescue, Jose Wheatgrass, Blue Panicum, and NK-37 Bermuda. Other grasses may be acceptable in particular parts of the country. Leafy plants should be avoided when sprinkler application is used because of leaf burn due to the high total dissolved solids concentration in most meatpacking plant wastewaters.

DESIGN CONSIDERATIONS

The design of a land application system must include several considerations. These include loading rates, operating pressure, and monitoring.

Loading Rates

For meatpacking plant wastewaters, there are three primary loading rates which must be taken into consideration in designating a system: the hydraulic loading rate, the organic loading rate, and the nitrogen loading rate.

The hydraulic loading rate is rarely the limiting loading rate for meatpacking plant wastewaters because of the high Biochemical Oxygen Demand

and nitrogen concentrations usually present in the plant effluent. Therefore, the hydraulic loading rate for most meatpacking plant wastewater would be less than 4 in/wk. Such a low hydraulic loading rate would dictate an infiltration system with sprinkler application in order to achieve a uniform distribution. When the wastewater has been treated beyond primary treatment, however, overland flow or infiltration via flooding can be considered. Witherow (5) has shown that a high degree of treatment can be attained through overland flow of meatpacking plant wastewater which had been previously subjected to treatment in anaerobic lagoons. Flood infiltration basins can also be used when relatively high quality wastewater is available and the soil and topographic conditions are acceptable.

The organic loading rate is usually the controlling factor for meatpacking plant wastes. The organic loading rate should not exceed 200 lbs BOD/acre/day when odor prevention is of primary concern. Higher rates can be used with good treatment results when the application site is away from populated areas.

The nitrogen loading rate must also be controlled when prevention of groundwater deterioration is of primary concern. The wastewater cannot be applied in amounts that would provide more nitrogen than the vegetation can assimilate. The amount of wastewater that could be applied, therefore, is dependent on the nitrogen concentration in the wastewater and the type of soil cover used. For an overland flow system, a travel distance of at least 200 feet should be used. For high strength wastewaters, a longer travel distance will improve effluent quality.

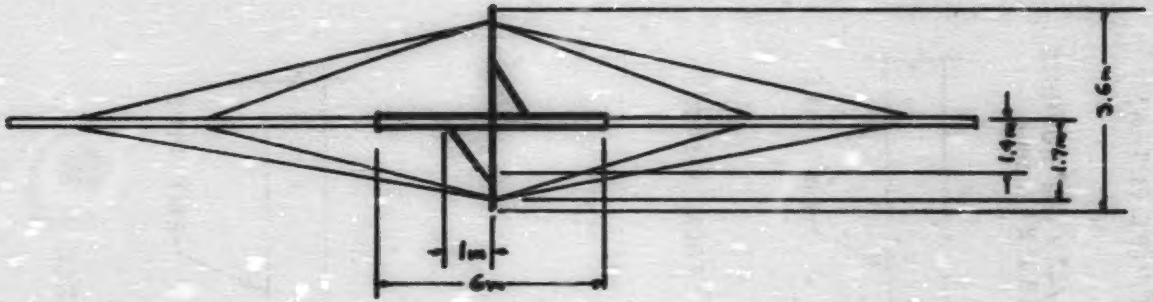
Pressure

Land application systems have been operated successfully at both high (90 psi) and low (10 psi) working pressures. The low pressure system has the advantage of reduced aerosol drift during wastewater application, but the disadvantage of increased initial investment cost. The increased initial cost could be offset by the lower annual operating costs due to the low pressure.

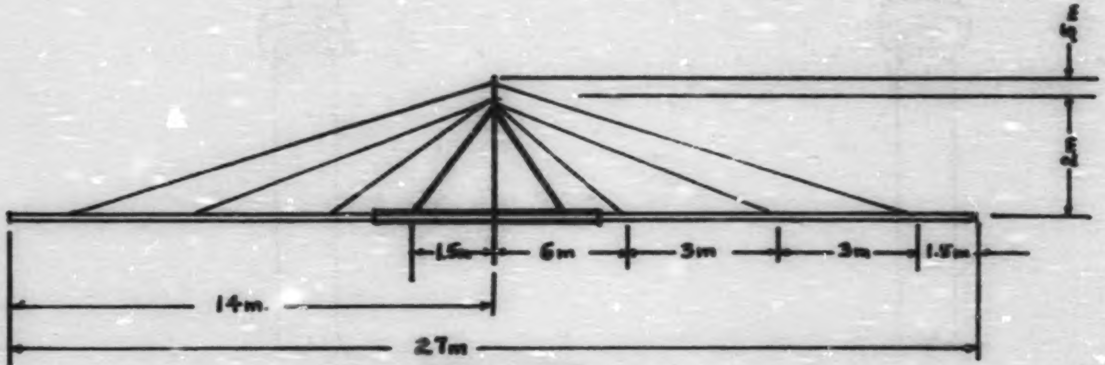
Various types of low pressure systems can be used. Figures 1 through 4 show the details of a low cost, low pressure (i.e. 10 psi) wastewater distributor. Figure 5 shows a very simple low pressure wastewater distributor suitable for an overland flow system. The absence of moving parts in this design is very attractive from the standpoint of maintenance. Other deisgns for low pressure distribution systems are commercially available.

Monitoring

An adequate monitoring system should be an integral part of any type of land application system. For an infiltration system, this should include soil samples for measuring the quality of the percolated wastewater as a function of downward travel distance. In addition, at least one groundwater sampling well should be placed in the center of the treatment area


1m
6m
1.4m
1.7m
3.6m

TOP VIEW


.5m
2m
1.5m
6m
3m
3m
1.5m
14m.
27m

SIDE VIEW

Fig. 1. LOW PRESSURE DISTRIBUTOR

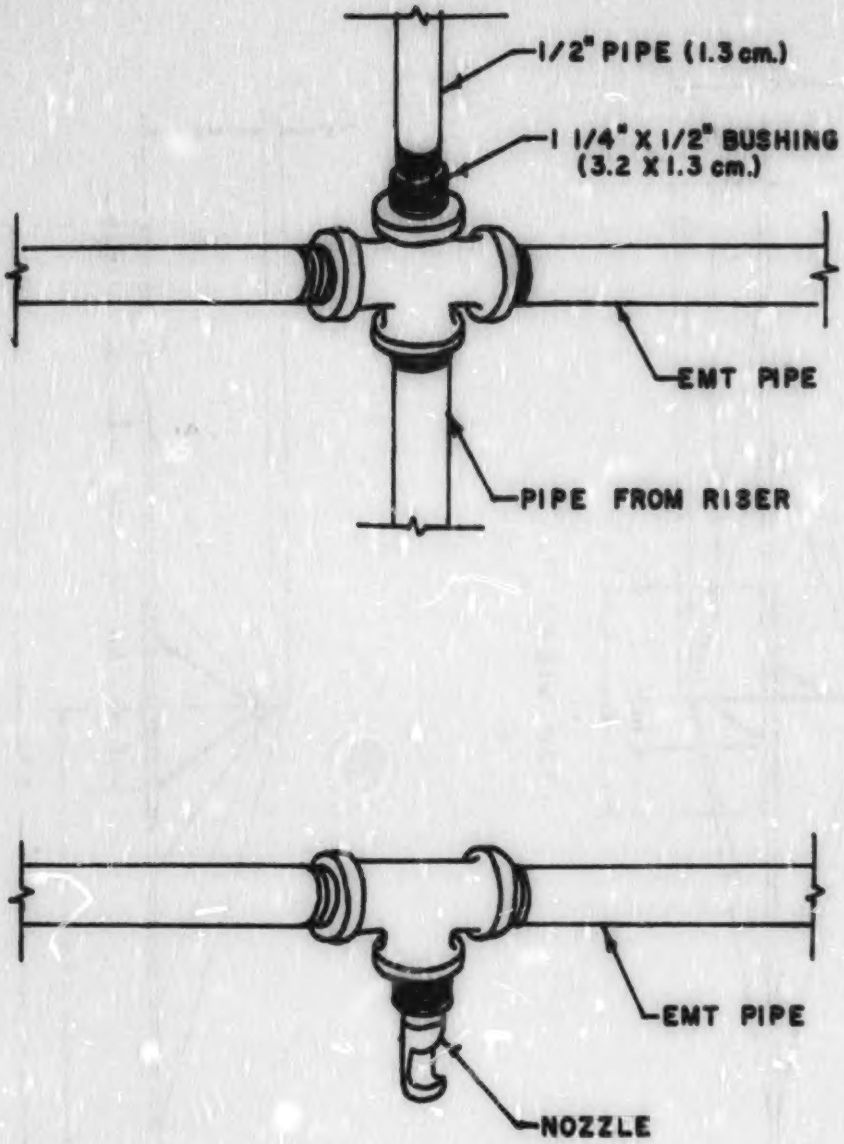

1/2" PIPE (1.3 cm.)
1 1/4" X 1/2" BUSHING (3.2 X 1.3 cm.)
EMT PIPE
PIPE FROM RISER
EMT PIPE
NOZZLE

Fig.2 DETAILS OF FITTINGS FOR DISTRIBUTOR

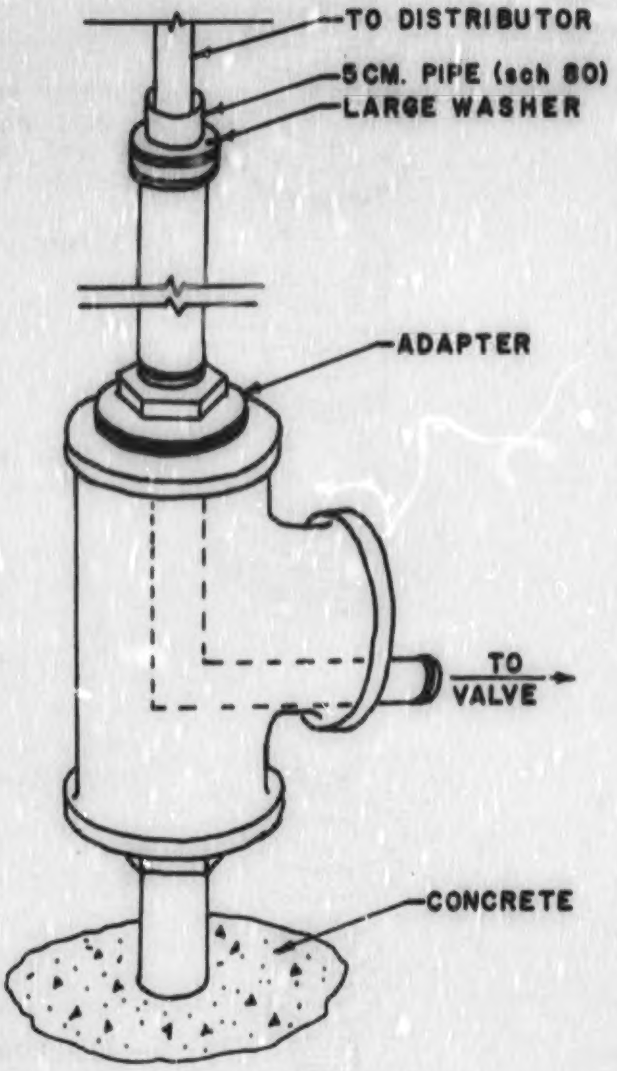

TO DISTRIBUTOR
5CM. PIPE (sch 80)
LARGE WASHER
ADAPTER
TO VALVE
CONCRETE

Fig.3 DISTRIBUTOR RISER
(See Fig 4 for exploded view)

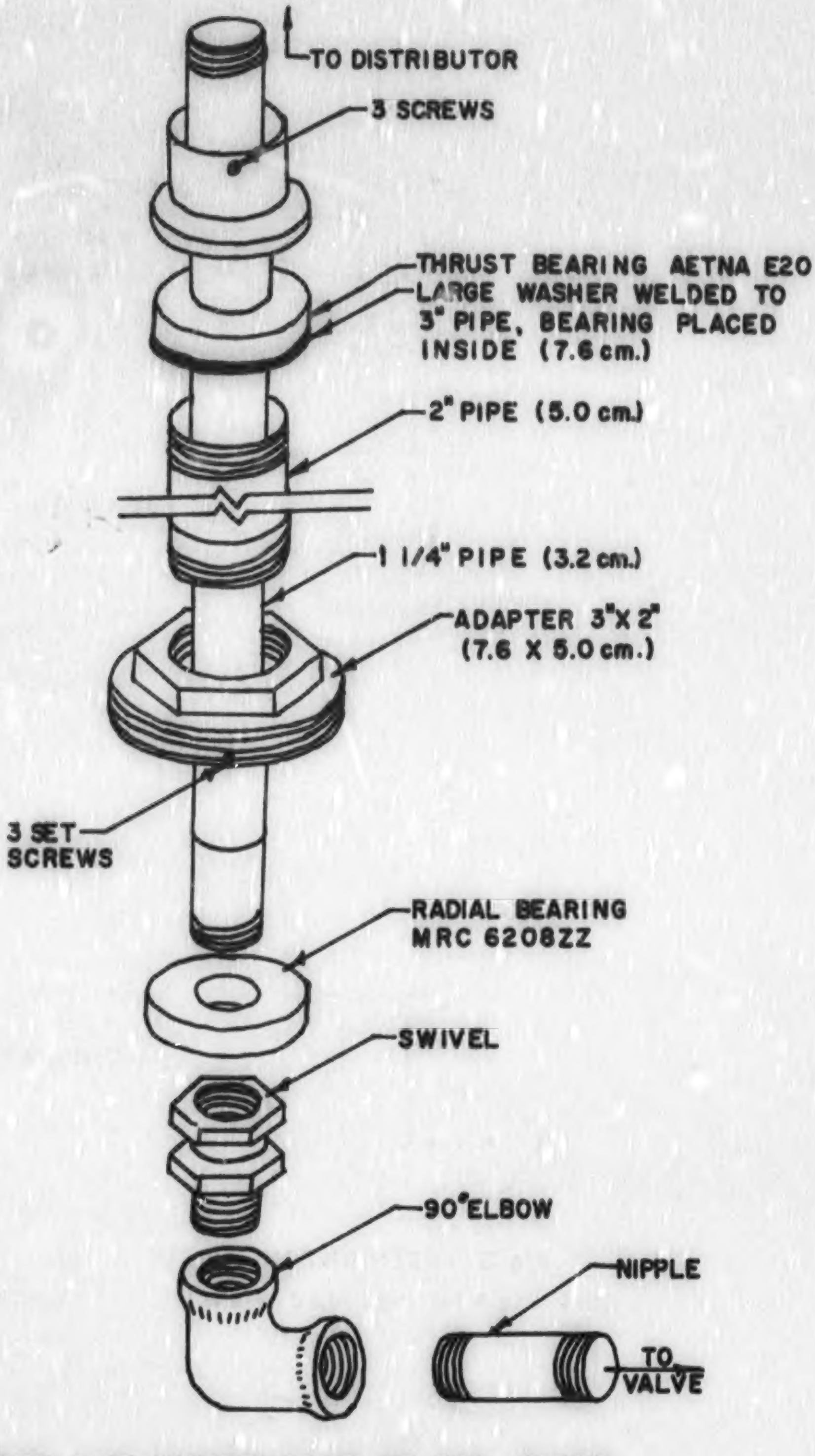
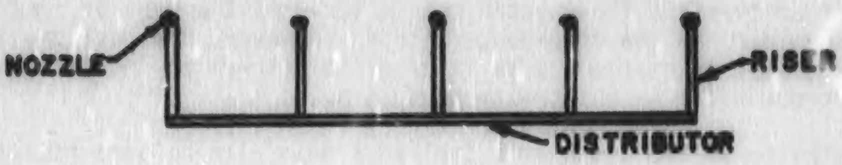
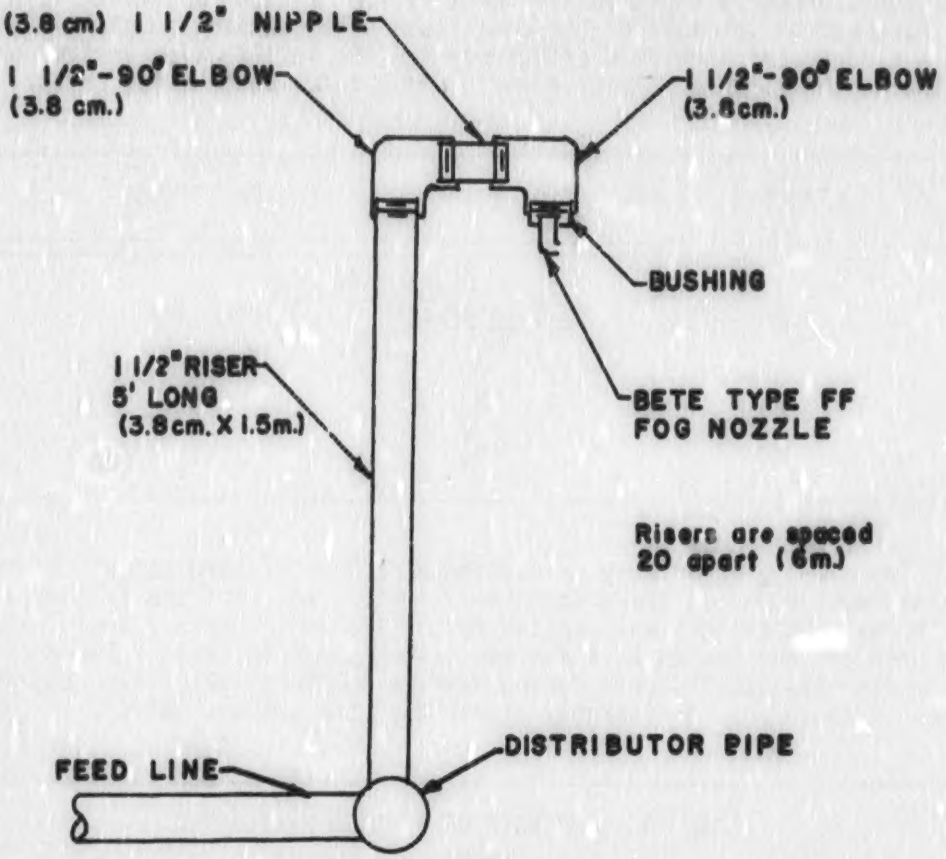

TO DISTRIBUTOR
3 SCREWS
THRUST BEARING AETNA E20
LARGE WASHER WELDED TO 3" PIPE, BEARING PLACED INSIDE (7.6 cm.)
2" PIPE (5.0 cm.)
1 1/4" PIPE (3.2 cm.)
ADAPTER 3"X 2" (7.6 X 5.0 cm.)
3 SET SCREWS
RADIAL BEARING MRC 6208ZZ
SWIVEL
90° ELBOW
NIPPLE
TO VALVE

Fig. 4. DETAILS OF CONSTRUCTION OF THE RISER


NOZZLE
RISER
DISTRIBUTOR

FRONT VIEW


(3.8 cm) 1 1/2" NIPPLE
1 1/2"-90° ELBOW
(3.8 cm.)
1 1/2"-90° ELBOW
(3.8cm.)
BUSHING
BETE TYPE FF
FOG NOZZLE
1 1/2" RISER
5' LONG
(3.8cm. X 1.5m.)
FEED LINE
DISTRIBUTOR PIPE

Risers are spaced
20 apart (6m.)

SIDE VIEW

Fig. 5 LOW PRESSURE RUNOFF AREA DISTRIBUTOR

and one placed at the edge of the treatment area in the direction of the groundwater flow. Well water samples should be taken at least monthly in order to observe any possible deterioration of the groundwater.

For an overland flow system only a very small amount of applied wastewater should reach the groundwater table. However, at least one well should be placed in the treatment area in order to observe any possible contamination of the groundwater by the treatment system.

Sampling of the wastewater applied should also be done regularly so that the efficiency of the system can be determined. These results will also serve as a basis for future expansion.

TREATMENT EFFICIENCY

For a properly operated treatment system, a high removal efficiency can be expected for most of the constituents of meatpacking plant wastewater. Table 2 shows the treatment efficiency for the infiltration system operated at the Peyton Packing Company for 2.5 and 4 in/wk application rates.

TABLE 2. INFILTRATION SYSTEM TREATMENT EFFICIENCY

Parameter	Percent Removal 2.5 inch/week	 4 inch/week
Grease	100	100
COD	99	98
Nitrogen	72	58
SS	100	100

The average efficiency values shown in Table 2 were calculated from the wastewater values shown in Table 3, which represent the average strength of the wastewater that was applied to the treatment areas. These values are greater than the 24 hour average values shown in Table 1 because wastewater was applied only during daytime hours, at which time the wastewater strength was considerably higher than the average values.

TABLE 3. STRENGTH OF APPLIED WASTEWATER

Parameter	Concentration, mg/l
BOD	5,800
COD	9,400

TABLE 3. STRENGTH OF APPLIED WASTEWATER (Continued)

Parameter	Concentration, mg/l
Grease	2,600
Total Kjeldahl Nitrogen	160
SS	3,140

As shown in Table 2, all of the grease was removed at both the 2.5 and 4 in/wk application rates. This is as expected, since most of the grease that was present in the wastewater was in the form of coagulated particles. The filtration of the grease by the soil was evident from visual observation of the soil surface after several weeks of wastewater application. However, after drying periods of one to two weeks duration, periodic soil analysis failed to show measurable amounts of grease in the surface soil samples (i.e., 0-1 inch) during the entire time this study was conducted.

The COD removal was excellent at both wastewater application rates studied, particularly in view of the extremely high organic loading rates employed. These rates were 1,975 lbs COD/acre/wk at the 2.5 inch rate and 3,293 lbs COD/acre/wk at the 4 inch rate. These results show the excellent treatability of meatpacking plant wastewater by land application.

The high organic loading rates caused some problems with infiltration and odors, particularly at the higher loading rate. At approximately 3 week intervals, it was necessary to omit one or more of the application periods in order to allow adequate drying time. If this were not done, the reduced infiltration rate would cause ponding with subsequent odor, and insect problems.

Nitrogen removal was also very good when the high loading rates are taken into account. The 2.5 in/wk hydraulic loading rate resulted in a 1,750 lbs/acre/yr loading while the nitrogen loading at the 4 in/wk rate was 2,914 lbs/acre/yr. Both values are much higher than the normal application rates recommended for agricultural fertilization. In terms of nitrogen removal 1,259 and 1,691 lbs/acre/yr were removed at the 2.5 and 4 in/wk application rates respectively. The nitrogen removals obtained, therefore, obviously could not be accounted for in plant uptake alone.

For the overland flow system, the results are shown in Table 4 below.

TABLE 4. OVERLAND FLOW TREATMENT RESULTS

Parameter	Influent Conc, mg/l	Effluent Conc, mg/l	% Removal
COD	9,440	1,495	84
Kjeldahl Nitrogen	185	108	44
Total Solids	7,430	3,420	54
Volatile Total Solids	4,690	1,125	76
Suspended Solids	4,130	535	87
Volatile Suspended Solids	3,825	420	89

As with the infiltration treatment system, the overall efficiency of the overland flow system was excellent when the extremely high organic loading rate is taken into consideration. The COD removal, for example, was 1,800 lbs/acre/day, or in terms of BOD, approximately 900 lbs/acre/day.

Slight odors were noticeable when the system was operated for more than three consecutive weeks without resting, but the odors disappeared quickly after irrigation was stopped.

Although there was a noticeable deposition of greasy looking solids at the edges of the sprinkler application area, these solids turned black and dried very well during resting periods. Utilization of a proper operating and drying schedule, therefore, seems to eliminate any problems which might be caused by solids build-up.

SUMMARY

The treatability of high strength meatpacking plant wastewater by land application has been shown to be excellent for both infiltration and overland flow type systems. With respect to organic carbon removal, both infiltration-percolation and overland flow systems have been shown to be very effective. The advantage of higher efficiency obtained with the infiltration system is offset somewhat by the more expensive and complicated distribution system involved. Additionally, recovery of the treated wastewater from an infiltration system would be more difficult if subsequent reuse were anticipated. There is also less likelihood of polluting potable water supplies with an overland flow system.

Nitrogen removal was also slightly better with the infiltration system than with overland flow. However, efficient nitrogen removal depends to a great extent on closely controlled operating conditions.

The potential for phosphorous removal is obviously greater in an infiltration system than overland flow. Where phosphorous removal is of primary importance, therefore, infiltration systems offer a definite advantage compared to overland flow. On the other hand, when soil conditions are not favorable for phosphorous removal and chemical treatment must be employed, there are few considerations which would favor one system over the other.

POTENTIAL PROBLEMS

There are several potential problems associated with land application of meatpacking plant wastewater. One of these which requires immediate consideration is the possibility of the presence of pathogenic bacteria in the wastewater. Brucella, Streptococcus, Staphlococcus, Salmonella, and Shigella bacteria have been isolated from the effluent of the catch basin on several occasiosns. The extent of this problem is not known at this time but should have a high priority in future studies or in proposed installations.

The problem of pathogenic bacteria present in the wastewater is compounded by the drifting of aerosols formed during application of the wastewater. Under even slight wind conditions (5-10 miles/hour) viable bacterial cells have been measured as far as 500 feet downwind for the high pressure system. For the low pressure distribution system, the maximum travel distance downwind was less than 100 feet. It is obvious, therefore, that this problem should be given careful consideration in designing a distribution system, with lower operating pressures preferred.

The high TDS concentration in most meatpacking plant wastewaters is caused by sodium chloride. As a result, most packing plant wastewaters have a very unfavorable sodium absorption ratio. This would cause serious problems with infiltration in clay-containing soils unless amendments were added. Sandy type soils are generally not affected by unfavorable sodium adsorption ratios and therefore are generally best suited for accepting meatpacking plant wastes as they leave the plant.

Finally, the high concentration of nitrogen present in most meatpacking plant wastewaters presents a potential problem of ground water pollution. The experience gained with soil treatment systems so far indicates that close control of the treatment system is required in order to remove greater than 50 percent of the nitrogen. Even then, the high concentration originally present could cause significant amounts of nitrogen to reach the ground water table.

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SEVENTH FOOD WASTE SYMPOSIUM

REGISTRATION LIST

C. D. AKRIDGE
Swift Fresh Meats Company
P.O. Box 729
Moultrie, GA 31768

DON ALLEN
GA Dept. of Natural Resources
270 Washington St., SW
Atlanta, GA 30334

JAMES B. ALLEN
MS State University
Box 5465
Mississippi State, MS 39762

GEORGE BARNES
City of Atlanta
302 City Hall
Atlanta, GA 30303

JOHN C. BARNES, JR.
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Box 389
Kilmarnock, VA 22482

J. H. BAUER
96 Popular St., NW
Atlanta, GA 30303

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308 Main Street
New Rochelle, NY 10801

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P.O. Box 3508
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96 Poplar St., NW
Atlanta, GA 30303

JOHN BENEMANN
SERL
University of CA
Berkeley, CA 94720

P. M. BERTHOUEX
University of WI
Madison, WI 53705

D. WAYNE BISSETT
Water Pollution Control Directorate
Environment Canada
Ottawa, Ontario K1A 0H3

DAN BLACKSHEAR
J-M Poultry
422 N. Washington
El Dorado, AR 71730

JOHN BOMBEN
USDA-WRRL
800 Buchanan Street
Berkeley, CA 94710

HENRY BOROW
Standard Brands Ltd.
550 Sherbrooke St. W.
Montreal, Quebec H3A 1B9

GARY J. BOTTOMLEY
Holly Farms Poultry Inc.
P.O. Box 88
Wilkesboro, NC 28697

WAYNE BOUGH
University of GA
Dept. of Food Services
Experiment, GA 30212

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GREG BUCOVE
University of WA
College of Fisheries
Seattle, WA 98195

ROBERT W. BURNS
J-M Poultry Packing Co.
P.O. Box 1758
El Dorado, AR 71730

CLARK CALLAWAY
NCSU Seafood Laboratory
P.O. Box 51
Morehead City, NC 28557

THOMAS CAMPBELL, JR.
University of GA
Georgia Station
Experiment, GA 30212

GERALD CARLSON
North Carolina State
Raleigh, NC 27207

WALLACE CARPENTER
Environmental Protection Div.
270 Washington St., SW
Atlanta, GA 30334

JOHN F. CHAPPLE
Bio-Viro-D, Inc.
2045 Spafford Ave.
West Palm Beach, FL 33409

MARVIN CHARLES
LeHigh University
Bethlehem, PA 18015

T. C. CHEN
MS State University
Box 5188
Mississippi State, MS 39762

REX E. CHILDS
Russell Research Center, ARS
720 Sunnyside Drive
Athens, GA 30601

H. S. CHRISTIANSEN
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Los Angeles, CA 90036

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Temperanceville, VA 23442

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Mountainaire Corp.
Suite 1050, Plaza West Bldg.
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EDWIN COX III
Edwin Cox Associates
P.O. Box 8025
Richmond, VA 23223

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5900 Ogden Avenue
Cicero, IL 60650

MICHAEL S. CREASON
GA Environmental Protection Div.
270 Washington St., SW
Atlanta, GA 30334

BARNEY CULVER
Culver Duck Farm
12215 CR 10
Middlebury, IN 46540

BOB D'AGOSTARO
CH$_2$M-Hill
1930 Newton Square
Reston, VA 22090

STEPHEN D. DANIEL
Central Soya
Box 907
Canton, GA 30114

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Madison, WI 53701

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THOMAS E. ELLIOTT
Swift Fresh Meats Co.
115 W. Jackson Blvd.
Chicago, IL 60604

S. DAVID ELLISON
CH$_2$M-Hill
1930 Newton Square
Reston, VA 22090

E. E. ERICKSON
Northstar Division MRI
3100 38th Avenue S.
Minneapolis, MN 55406

TERRY ERVIN
Development Engr.
Turbitrol Company
415 E. Paces Ferry Rd.
Atlanta, GA 30305

JOHN B. ESKEW
Gold Kist Research Ctr.
P.O. Box 388
Lithonia, GA 30058

L. CLIFF EVANS
AL State Health Dept.
State Office Bldg.
Montgomery, AL 36130

JOHN W. FARQUHAR
American Frozen Food Inst.
919 18th Street, NW
Washington, DC 20006

WILLIAM J. FARRISEE
International Bakerage, Inc.
3300 NE Expressway
Atlanta, GA 32041

RICHARD T. FERRY
Bio-Viro-D, Inc.
2045 Spafford Ave.
West Palm Beach, FL 33409

GUNNAR FINNE
Clemson Univ. Ext. Service
P.O. Box 3158
Charleston, SC 29407

D. W. FLOOD
Maple Leaf Mills Ltd.
417 Queen's Quay W.
Toronto, Ontario M5W 1C7

HAROLD E. FORD
Southeastern Poultry & Egg Assoc.
1456 Church Street
Decatur, GA 30030

ALAN FOSTER
Canada Packers Ltd.
95 St. Clair Avenue W.
Toronto, Ontario M4V 1P2

R. A. GALLOP
University of Manitoba
Food Science Department
Winnipeg, Manitoba R3T 2N2

FRED A. GARDNER
Texas Agric. Experiment Station
Texas A&M University
College Station, TX 77840

JEAN R. GEISMAN
The Ohio State University
2001 Fyffe Court
Columbus, OH 43210

STEVEN GLASS
Maplewood Poultry Co.
Belfast, ME 04915

K. C. GOEL
E. H. Richardson Assoc.
P.O. Box 935
Dover, DE 19901

JOHN H. GREEN
U.S. Dept. of Commerce
Southeast Utilization Res. Ctr.
College Park, MD 20740

DAVID L. GROTHMAN
Oscar Mayer & Co.
910 Mayer Avenue
Madison, WI 53704

C. FRED GURNHAM
Gurnham & Assoc., Inc.
223 W. Jackson Blvd.
Chicago, IL 60606

REGINALD L. HANDWERK
Food & Drug Admin.
200 C Street SW
Washington, DC 20204

GEORGE HARRISON IV
Knoxville Poultry & Egg Co.
P.O. Box 3220
Knoxville, TN 37917

ROBERT L. HAYNES
MS State University
P.O. Box 542
Mississippi State, MS 39762

R. L. HAYS
CPC International
Box 345
Argo, IL 60501

LEVEN HENDERSON
Pomona Products Co.
P.O. Drawer B
Griffin, GA 30224

ROBERT C. HOEHN
VA Polytechnic & State Univ.
Civil Engineering Dept.
Blacksburg, VA 24061

CHUCK HOFFMAN
Magnuson Engr. Inc.
1010 Timothy Drive
San Jose, CA 95133

RAY HOLYFIELD
GAMCO
Gainesville, GA

JOSEPH A. HOMAL
Foth & Van Dyke & Assoc.
1970 South Broadway
Green Bay, WI 54304

JOHN L. HOPKINS III
VA Egg Producers
McGaheysville, VA 22840

DENNIS L. JOHNSON
Swift Fresh Meats Co.
115 W. Jackson Blvd.
Chicago, IL 60604

G. ROBERT JOHNSON
Popham, Haik, Schnobrich,
Kaufman & Doty, Ltd.
4344 IDS Center
Minneapolis, MN 55402

JOE M. JONES
Peterson Industries
Box 128
Decatur, AR 72722

CHRISTINE A. KAHR
James M. Montgomery Consulting
Engineers, Inc.
1990 N. California Blvd.
Walnut Creek, CA 94596

ERWIN KIEFER
Patrick Cudahy, Inc.
4801 S. Kingan Avenue
Cudahy, WI 53110

MONTE W. KORB
Korb Engineering Co.
609 Beachview Drive
St. Simons, GA 31522

VACLAV KRESTA
New Brunswick Dept. of the
Environment
P.O. Box 6000
Fredericton, NB

ARUN R. KUMBHARE
Environment Canada
P.O. Box 2406
Halifax, Nova Scotia B3J 3E4

K. D. KURTZ
Clark & Vicario Corp.
9620 Executive Ctr. Dr. N.
St. Petersburg, FL 33702

KENNETH LA CONDE
SCS Engineers
4014 Long Beach Blvd.
Long Beach, CA 90807

JOSE S. LAGAHIT III
Libby, McNeil & Libby
200 S. Michigan Ave.
Chicago. IL 60684

JOHN S. LAMICA
The Turbitrol Co.
415 E. Paces Ferry Rd.
Atlanta, GA 30305

WILLIAM LANHAM
Green Acre Farms Inc.
P.O. Drawer B
Sebastopol, MS 39359

JEAN LAPERRIERE
Services de Protection
de l'Environnement
255 Cremaxie est
Montreal, Quebec H2M 1L5

LES LASH
ENVIROTECH
Box 300
Salt Lake City, UT 84110

JOE L. LAY, JR.
Lay Packing Co., Inc.
P.O. Box 2447
Knoxville, TN 37901

FERNAND L'ECUYER
Cooperative Federee de Quebec
Montreal, Quebec

JEAN S. LENNON
FMC Corporation
1185 Coleman Avenue
Santa Clara, CA 95052

SERGE LESSARD
Villina, Fortier & Assoc.
3300 Cavendish Suite 385
Montreal, Quebec H4B 2M8

HUDA S. LILLARD
USDA-ARS
Russell Research Center
Box 5677
Athens, GA 30601

S. S. LIN
Kramer, Chin & Mayo, Inc.
1917 1st Avenue
Seattle, WA 98101

J. ALEC LITTLE
U.S. EPA
1421 Peachtree St.
Atlanta, GA 30309

EDMOND P. LOMASNEY
Southeast Region, EPA
1421 Peachtree Street
Atlanta, GA 30309

A. W. LOVEN
Engineering Science, Inc.
57 Executive Park South
Atlanta, GA 30329

DONALD MacGREGOR
O'Brien & Gere Engineers, Inc.
1231 Wildflower Drive
Webster, NY 14580

ELTON MADDOX
Wayne Poultry Co.
P.O. Box 69
Pendergrass, GA 30567

RICHARD F. MATTHEWS
University of FL
325 Food Science Bldg.
Gainesville, FL 32611

ROBERT G. McELROY
USDA-Russell Res. Ctr.
Athens, GA 30601

CHARLES V. McREYNOLDS
Blue Star Foods
1023 4th Street
Council Bluffs, IA 51501

ROBERT E. MEANS
Bouillon, Christofferson
& Schairer
5050 Washington Bldg.
Seattle, WA 98101

WALTER A. MERCER
National Canners Assoc.
1950 Sixth Street
Berkeley, CA 94710

JERRY R. MEYER
Ollie Meyer, Inc.
1584 Tullie Circle
Atlanta, GA 30328

JAMES M. MOREAU
L. A. Frey, Inc.
P.O. Box 51507, OCS
Lafayette, LA 70501

DALE MORRIS
Mar-Jac Inc.
P.O. Box 49
Gainesville, GA 30501

FRANK B. MURPHY
ALCOA
ATC - Bldg. D
Alcoa Center, PA 15069

KEVIN McCANN
Autotrol Corp.
5855 N. Glen Park Rd.
Glendale, WI 53209

DANIEL T. McGRAIL
State of MD Dept. of
Health & Mental Hygiene
201 E. Preston Street
Baltimore, MD 21201

DAVID J. McNAIR
Allied Mills, Inc.
110 N. Wacker Drive
Chicago, IL 60606

LAURA McQUINN
American Meat Inst.
P.O. Box 3556
Washington, DC 20007

JACK McVAUGH
Envirex Inc.
Box 1067
Waukesha, WI 53186

CARL E. NALL
Pacific Egg & Poultry Assoc.
5320 W. Jefferson Blvd.
Los Angeles, CA 90016

CARL D. NELSON
AL State Health Dept.
State Office Bldg.
Montgomery, AL 36130

PETER NI
Patrick Cudahy, Inc.
4801 S. Kingan Ave.
Cudahy, WI 53110

LEON A. NOLTING
A. E. Staley Mfg.
East Past Road
Monesville, PA 19067

RAYMOND L. NOTARO
Campbell Soup Co.
Campbell Place
Camden, NJ 08101

G. B. OGLESBY
GA Dept. of Natural Resources
270 Washington St., SW
Atlanta, GA 30334

C. M. PARKS
MS Cooperative Extension
State College, MS 39762

JOHN P. PILNEY
North Star Div. MRI
3100 38th Avenue S.
Minneapolis, MN 55406

JEFF PINTENICH
Engineering Science, Inc.
57 Executive Park South, NE Suite 590
Atlanta, GA 30329

NAGARAJA P. PGO
Arthur G. McKee & Co.
10 S. Riverside Plaza
Chicago, IL 60606

MARSHALL W. RAY
CAN TEX Industries
P.O. Box 340
Mineral Wells, TX 76067

GENE REECE
Peterson Industries
Box 128
Decatur, AR 72722

JIM ROBINSON
Sanderson Farms, Inc.
P.O. Box 2937
Laurel, MS 39440

WALTER W. ROSE
National Canners Assoc.
1950 Sixth Street
Berkeley, CA 94710

M. L. ROWE
East Central University
Ada, OK 74820

JOHN RUGABER
Pet, Inc.
St.Louis, MO

LARRY L. RUSSELL
James M. Montgomery Consulting
Engineers, Inc.
1990 N. California Blvd.
Walnut Creek, CA 94596

WILLIAM D. RUTZ
MAPCO, Inc.
1437 S. Boulder Ave.
Tulsa, OK 74119

JOHN E. SAUVAGE
Swift Dairy & Poultry Co.
115 W. Jackson Blvd.
Chicago, IL 60604

GEORGE A. SCHULER
University of GA
Athens, GA 30601

WILLIAM SCHULTZ
USDA-WRRL
800 Buchanan St.
Albany, CA 94710

LARRY J. SCULLY
Peat, Marwick & Mitchell Co.
1025 Connecticut NW
Washington, DC 20036

KHEM SHAHANI
University of NE
Dept. of Food Science
Lincoln, NE 68583

ED SHEFFIELD
Lou-Ana Foods, Inc.
P.O. Box 591
Opelousas, LA 70570

ROBERT SHERMAN
Wilson & Co.
4545 N. Lincoln Blvd.
Oklahoma City, OK 73132

A. L. SHEWFELT
GA Experimental Station
Experiment, GA 30212

LACY W. SIMMONS
Simmons Engineering Co.
P.O. Box 157
Roswell, GA 30075

JEFFRY P. SMITH
GA Dept. of Natural Resources
270 Washington St., SW
Atlanta, GA 30334

MIKE SMITH
McGill Grogan & Assoc.
P.O. Box 1454
Gainesville, GA 30501

R. E. SPEECE
Drexel University
32nd & Chestnut
Philadelphia, PA 19104

R. G. STENSGAARD
SWECO, Inc.
P.O. Box 4151
Los Angeles, CA 90051

NATHAN L. STEPHENS
Gold Kist Research Center
2230 Industrial Blvd.
Lithonia, GA 30058

RICHARD W. STERNBERG
U.S. EPA - Permits Division
Crystal Mall #2
Washington, DC 20460

CHARLES STEVENSON
Curtice-Burns, Inc.
P.O. Box 670
Rochester, NY 14602

HERBERT E. STONE
Del Monte Corporation
P.O. Box 3575
San Francisco, CA 94119

RAY STROUP, JR.
Lou-Ana Foods
112 Baudoin
Lafayette, LA 70501

GILMAN SYLVESTER
R. P. General Mgr.
Oakland, MD 21550

A. J. SZABO
Domingue, Szabo & Assoc.
P.O. Box 52115
Lafayette, LA 70505

ANTHONY J. TARQUIN
Univ. of TX at El Paso
Dept. of Civil Engineering
El Paso, TX 79968

VIRGINIA C. TAYLOR
Ruel Taylor, Inc.
198 Main Street
Gorham, ME 04038

MORRIS A. THOMAS
J-M Poultry Packing Co.
P.O. Box 1810
Gainesville, GA 30501

JAMES E. THOMSON
USDA-Russell Res. Ctr.
P.O. Box 5677
Athens, GA 30604

NORA K. THUMA
Atlantic Research Corp.
5390 Cherokee Avenue
Alexandria, VA 22314

TERRY C. TITUS
Clemson University
Food Science Dept.
Clemson, SC 29631

FRANK TODD
MFC Services (AAL)
P.O. Box 449
Jackson, MS 39205

WARREN K. TROTTER
USDA-Russell Res. Ctr.
P.O. Box 5677
Athens, GA 30604

RONALD A. TSUGITA
James M. Montgomery Consulting
  Engineers, Inc.
1990 N. California Blvd.
Walnut Creek, CA 94596

J. M. Vandepopuliere
University of MO-Columbia
Poultry Dept., T-14
Columbia, MO 65201

BILL O. VAUGHN
Ralston Purina Co.
835 S. 8th Street
St. Louis, MO 63188

YVONNE VIZZIER
Marshall Durbin Co.
111 Millsaps Avenue
Jackson, MS 39202

K. S. WATSON
Kraftco Corp.
801 Waukegan Rd.
Glenview, IL 60025

EDWARD K. WELLMEYER
Swift and Co.
115 W. Jackson Blvd.
Chicago, IL 60604

OTTO W. WENDEL
Bio-Viro-D, Inc.
2045 Spafford Ave.
West Palm Beach, FL 33409

W. K. WHITEHEAD
USDA-Russell Res. Ctr.
P.O. Box 5677
Athens, GA 30604

ROGER WILKOWSKE
Extension Service
USDA
Washington, DC 20250

GEORGE E. WILSON
EUTEK
1828 Tribute Rd., Suite H
Sacramento, CA 95815

SAM K. WINFREE
University of TN
P.O. Box 1071
Knoxville, TN 37901

FRANK WOODARD
University of ME
350 Aubert Hall
Orono, ME 04473

MALCOLM E. WRIGHT
VPI & SU
Agric. Engr. Dept.
Blacksburg, VA 24061

ARNOLD C. M. WU
University of GA
GA Exp. Station
Food Science Dept.
Griffin, GA 30212

FRED S. YOUNG
Environmental Products, Inc.
P.O. Box 2385
Hickory, NC 28601

ROBERT R. ZALL
Cornell University
Dept. of Food Science
Ithaca, NY 14853

BARRY ZUBKE
Mar-Jac, Inc.
P.O. Box 49
Gainesville, GA 30501